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ILLUSIONS OF THE SENSES:

AND OTHER ESSAYS.

BY

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PROFESSOR LE CONTE of the California University has recently published in the *North American Review* an interesting paper on the Evidence of the Senses, in which he shows that on the one hand the senses often afford most incorrect information while on the other the powers of such scientific instruments as give exact information would be utterly unsuitable substitutes for our less exact senses. Sight tells us that an object is flat when it is round, touch that an object is double when it is single, hearing that sounds come from close by when they really reach us from a great distance; but on the other hand to have eyes with telescopic power, or fingers as sensitive as a chemist's balance, or ears with the sound-gathering qualities of the microphone, would unfit us for the kind of life we have to lead upon this work-a-day world of ours.

I propose now to discuss the question dealt with by Le Conte, with special reference to the liability of our senses to various forms of error. Taste and smell need not here occupy our attention. They are less used than the other senses in scientific research; and so far as the purposes to which they are chiefly directed are concerned they are in the main trustworthy. They may deceive us by presenting as pleasant what is really deleterious, but once experience has determined the qualities and effects of substances having such and such taste or odor, we are not often deceived in identifying those substances thereafter.

The sense of touch is commonly understood as including the sense of heat-effects. But here, as Reid long since pointed out, our division of the senses is unsound. Undoubtedly the sense of touch is entirely distinct from the sense of heat,—though we may be said to *feel* in both cases. The error probably arose from the circumstance that the same organs seem employed in noting the effects of contact and the effects of heat. I touch a surface to see if it is hard or soft, rough or smooth, just as I touch a surface to see if it is hot or cold; moreover there is no part of the body which is sensible to the effects of contact which is not also sensible to the effects of heat and cold. But we recognize a marked difference between the sense of touch when the tip of the tongue is employed for the moment as the organ of touch, and the sense of taste; yet the difference between taste and touch is not more marked than the difference between heat and touch.

Therefore in dealing with errors

affecting the evidence given by the sense of touch, I consider only those really relating to the effects of contact, dealing separately with those relating to the effects of heat and cold.

Aristotle long since pointed out how the sense of touch may be deceived when the organs of touch are employed in some unaccustomed manner. It was he who first mentioned, if he did not invent, the experiment of rolling a pea between the tips of the first and second fingers, after the second finger has been crossed over the first. This experiment is instructive as showing how much of the significance of the teachings of our senses may be due to the effect of long-continued training. Every time we touch with the finger-tips an object of known shape, we are in reality teaching our fingers that such and such impressions have such and such a meaning. When two fingers are crossed, the finger-tips receive different impressions from those which they receive in their normal position, and we naturally misinterpret the meaning of the impressions so received. Thus if I touch with my first and second fingers the sides of a space shaped thus $\smile$, the outsides of the fingers come in contact with the curved surface, whereas the insides of the fingers feel such a surface as this,—$\frown$: so soon as the fingers are crossed these effects are reversed; the outsides of the fingers are brought together by the crossing and touch a surface shaped thus $\frown$, telling us apparently that it is really a surface shaped thus $\smile$ that we are touching. To test this apply the crossed fingers to a surface shaped $\frown\frown$, so that the fingers touch the convex curves near their place of meeting; now we find that we no longer seem to be touching two curves, but one. It must be admitted, however, that this experiment is less striking than the other; the information conveyed by the finger-tips instead of seeming definitely and decidedly incorrect, appears but vaguely erroneous.

Let us try a few other experiments with crossed fingers. Take a pen-holder or pencil, and with first and second fingers crossed slide the finger-tips along the pencil or holder. If the eyes are closed the fingers seem to tell us emphatically that we are feeling two parallel rods. Yet if the eyes are directed to the finger-tips the illusion disappears. This is not, however, because the eyes assure us that there is but one pen or pencil; it is because the eyes show us that the fingers are crossed. To show that mere knowledge will not save us from the illusion, feel with the crossed fingers the tip of the nose. We know certainly that we have but a single nose-tip; yet the absurd and illusory feeling that we have two noses is immediately produced. The illusion is strengthened if the crossed finger-tips are caused to slide along the ridge of the nose. Very curious illusions are produced if the crossed finger-tips are carried along either lip, or between the lips, or along the bone ridge below either eye or along the ridge above the eye, or round the ear, and so forth. But in my own case, the oddest illusion of all is obtained by crossing the forefinger behind the little finger, (both being bent somewhat toward the palm, so that the second or third fingers are behind them) and then feeling with these crossed fingers the tip of the nose: for now, not only does the nose appear double, but *one nose appears to be longer than the other.* One can easily understand why this is. Under ordinary conditions the first and little fingers cannot at the same moment feel two bodies which are equidistant from the observer,—or let us say from the palm. If, for instance, we place the forefinger tip on the end of a white note on the piano, the little finger tip can only rest on the end of another white note by bending the hand: we can, however, touch an end of a black note with the forefinger tip while the third finger tip touches the end of a black note, without bending the hand. The lesson taught, then,

by constant experience (unnoticed through its very familiarity) is that two bodies so felt extend to different distances. But in the experiment with crossed forefinger and little finger, the finger-tips touch at the same moment the same nose-tip, which appears double because touched by the outside edges of the fingers, and the two noses appear of unequal length because it seems as though the little finger touched one while the forefinger touches the other, each of them at the tip.

Other singular effects may be produced by crossing the fingers, varying the combinations. If the forefinger and second finger of the left hand be crossed as well as those of the right, and a small object be held between the crossed pair of each hand, the most incorrect ideas of the shape of the object are given. I have just tried the experiment, for instance, on a small box of pen-nibs, holding two opposite corners, one between the crossed finger-tips of the right hand, the other between those of the left hand; it was impossible to realize that the object thus held had any regularity of shape at all.

Another experiment on the sense of touch depends on the circumstance that usually the outsides of the hands are so placed that if both touch two surfaces at the same time those surfaces are not in the same direction. Of course the two hands can be placed side by side with their backs uppermost and a flat surface may so touch both; but usually the palms are toward each other, and this is especially the case when both hands are used in holding anything. Place the hands together, palm to palm, then cross the arms so that the hands are back to back; if now a book is held between the backs of the hands its edge appears bent. The force of this illusion is different with different persons; but let not those who are not affected by it rejoice as being less easily deceived than their fellows; for, as Sir David Brewster remarks in speaking of an illusion affecting sight, it often happens that the most observant are those most completely deceived by such illusions.

There is another curious illusion of touch which appears to depend on the teaching which the hands and arms have had (unconsciously) in estimating the dimensions of bodies held in the normal way, in front of the body. Suppose a book lying on a table before you, the back of the book being toward the right. Take hold of it by the nearest right-hand corner (that is, holding it by the end of the back nearest to you) and pass it over the right shoulder so that the face which had been uppermost lies against the back of the right shoulder in a nearly vertical position. Now pass the left hand round behind you under the left shoulder-blade till you can grasp with it the edges of the leaves. You will now find that though you *know* from the feel of the edges that your left hand holds a side several inches from the back held by the right hand, that side of the book appears to be a continuation of the back of the book,—so far as direction is concerned. The explanation appears to be simply this:—When an object like a book is held in front of the chest, the right hand holding one side, the left hand reaches the opposite side without effort or stretching; while with a slight amount of stretching the side held by the right hand can be reached; now when the book is held behind the back in the way described above, an effort is required to reach with the left hand the side opposite that held by the right, hence the same effect is produced on the mind as when in the normal way of holding objects of the kind the left hand is stretched over to the right hand's side of the object; thus instead of the left hand touching the side opposite that held by the right, it appears to touch the same side.

So much for illusions affecting touch. Or rather, these afford sufficient evidence that the sense of touch may be readily deceived. But in reality, scarcely a day passes without

our noticing, if we are at all observant, illusions affecting this sense. If we observe the circumstances under which such illusions occur we generally find that they arise when some organ of touch is used in a novel or unusual way. But in the majority of cases arising in ordinary life the sense of touch acts in combination with either the sense of sight or the sense of hearing, and consequently the illusions arising are not such simple examples of errors in the evidence afforded by the sense of touch as those considered above.

The sense of heat is in like manner usually associated with the sense of sight, so that illusions affecting it are either corrected or modified by visual impressions. Yet there are cases where this sense is deceived when acting alone. For instance, there is the well known experiment in which after one hand has been placed for a time in water as hot as can be borne, and the other in ice-cold water, both hands are plunged simultaneously into tepid water. Immediately the hand which had been in very hot water recognizes a comfortable sense of coolness, and as it were pronounces the water cold ; the other hand as quickly recognizes a comfortable sense of warmth and pronounces the self-same water hot. Here even sight will not correct the illusion. We see as plainly as possible that both hands are in the same basin, yet one hand seems to be in warm water, the other in cold. I find a singular effect produced if while the attention is strongly directed to the circumstance that both hands are in the same water, the hands are freely moved about in the water. For it seems then as though there were currents of hot and cold water in the same basin, moving so as to follow or rather to accompany the hands.

Without making definite experiment in this way, we can easily in the ordinary experiences of life, recognize the readiness of the heat sense to be deceived. Thus we come out of a warm room into the hall outside and find the air there pleasantly cool. We then, perhaps, see a friend home through the cold night air and presently return to the same hall. But now, coming into it from the cold outer air, we find it pleasantly warm.

Professor Le Conte remarks that "during the Arctic voyages made by Parry, Franklin, Ross, Kane, Nares, and others, it was found that a zero temperature seemed quite mild after the thermometer had been twenty or thirty degrees below that point." But, although in California temperatures of twenty or thirty degrees below zero may not be common, an American has no occasion to leave the United States, or even the middle states, to experience the illusion in question. I have repeatedly walked along the streets of New York with the temperature a degree or two below zero, without wearing an overcoat or feeling the want of one, when such a temperature has followed a few days of much colder weather. And conversely, even as I write I am feeling unpleasantly cold at Columbia, South Carolina, with the temperature only just below zero (and the air still), simply because I have been enjoying during the last few days in Charleston, S. C., a soft and balmy warmth resembling that of a June day in England.

Again, in caverns like the Mammoth Cave, Kentucky, or Kent's Hole in Devonshire, there is in summer always a sense of coldness and in winter always a sense of heat, yet in reality the thermometer shows that, as might be expected, the air is somewhat warmer within such caves in summer than it is in winter. Here, then the illusion is not only incorrect but the very contrary of the truth ; the air seems colder when it is really warmer and warmer when it is really colder. Because the range of temperature is much less within the cave than in the open air, we are deceived into the idea that the temperature really ranges the reverse way from that in which it actually varies.

A more subtle illusion relating to heat is that arising from difference in the conducting power of various substances with which the skin is brought into contact. Thus if we plunge into water of the very same temperature, when tested by the thermometer, as the surrounding air, both being really cooler than the body, the water seems cold, because being a better conductor than air, it immediately begins to carry off more of the body's warmth. On the contrary, the self-same substance—water—not only feels hot but is unbearably hot when at a temperature far below that of the surrounding air in a Turkish bath.

It is to be noticed that in this case the sense of heat while in one respect leading to an erroneous idea, in another and a much more important point gives correct information. If one were to trust the teachings of the thermometer, and infer that one might as well remain in water as in air seeing that the water and the air are of the same temperature, one would make a serious mistake, and suffer a good deal of harm through the rapid abstraction of warmth from the body. The heat sense, by telling us wrongly that the water is colder than the air, conveys at least the much more important information that we are losing heat while in the water,—and therefore saves us from the danger of getting unduly chilled, as we might if we trusted to the thermometer alone. In the reverse case, the sense of heat acts even more directly and emphatically for our benefit.

I remember a case in point which occurred at the Hummums. Some one who had heard that the temperature of water in the hot rooms is always much lower than the temperature of the air, but had not considered the matter with actual reference to the requirements of the human body, supposed that he would gain decidedly in comfort if instead of sitting on the non-conducting felt or flannel of the seats, he were to substitute a roll of towels well soaked in water. He found as a matter of fact that the arrangement thus suggested by the thermometer was very far from being welcomed by the nerves of touch,—whose repugnance to the arrangement was indeed most emphatic.

It is hardly necessary to say, perhaps, that the whole question of clothing, especially for young people, depends on the relation between the conducting powers of various substances used for clothing. In this matter the sense of heat gives more trustworthy information than the thermometer, clothes which seem to be of the same temperature if tested by the thermometer affording very different degrees of protection against the loss or the too rapid accession of heat.

In passing, I may note here an important consideration as to the clothing proper for children. In their case as in the case of grown folk the sense of heat gives the best information as to what is really desirable in the way of clothing. But grown people are apt to forget the experiences of their childhood, and to decide what is best for children from their own ideas as to what ought to be best. A child complains of cold or of heat sooner than a grown person; but much less attention is paid to the complaints of children on such matters than to our own slightest suggestions of personal discomfort. And children are much less carefully guarded against heat and cold than grown persons guard themselves. The idea seems to be that children can stand any changes of temperature; though, oddly enough, children's own idea (which is really not very far from the truth) that they can stand anything in the way of rich and indigestible eating, is not much considered by older persons. Now, when a child shows by its words or actions that it suffers sooner from changes of temperature than grown people do, it in reality expresses its sense of an important truth. A child cools and

warms more quickly than a man; for precisely the same reason that a small cinder cools more quickly than a large one, or that a small fire burns out more quickly than a large furnace. Compare the case of a child three feet high with that of a man six feet high. Neglecting slight differences of build, the man is about eight times as large as the child, or contains eight times as much matter. But the surface of the man is not eight times as large as the surface of the child; it is only four times as large. Thus supposing the man and the child to come out of a warm room into the cold outer air, being both at the same temperature, the man has eight times as much heat to part with as the child has; but he only parts with four times as much heat, moment by moment, if he and the child are similarly clothed. Thus the child's loss of heat, moment by moment, though only one-fourth of the man's loss of heat, bears twice as great a ratio to the child's total supply of heat. The child will cool as much in one minute as the man cools in two minutes, or in half-an-hour as the man cools in an hour. If the weather outside is so cold that the man would suffer serious injury to his health after an hour's exposure to it, the child will suffer at least an equal injury in half-an-hour. In reality, of course, the child will suffer a greater injury; because apart from his more rapid loss of heat, the child's flesh is more tender and necessarily suffers more from a given loss of temperature. Similar remarks apply to increase of heat, which may be just as mischievous as access of cold. Yet we are too apt to clothe children with total disregard to the circumstances that they require to be protected much more carefully than their elders against rapid changes of temperature. Apart from all questions of propriety, a man would not care even on a fairly warm spring day to go about with his arms and legs bare for any length of time; for he would feel uncomfortably cool: children suffer twice as much on such a day from undue exposure to the air; yet many foolish folk think nothing of exposing the delicate limbs of children to the cold of winter without protection. They imagine that the numbness and insensibility which really indicate the mischievous effects of the cold, and may permanently affect the the child's constitution, are signs of hardening; and because only the hardier survive this cruel treatment they imagine that those hardy survivors owe the strength which enabled them to survive, to the harsh exposures by which that strength was dangerously taxed and perhaps in large measure sapped.

It is, however, the sense of sight which has most thoroughly deceived the student of science, almost justifying Professor Le Conte's statement that no evidence is more misleading and fallacious than the evidence of the senses. So far from seeing being believing, one recognizes that often we see an object wrongly tinted, wrongly illuminated, wrongly shaped, besides that fault of wrong apparent size which we might expect to recognize in the case of a sense like sight (which gives no direct evidence as to distance).

Taking this last defect of sight-evidence first, we note that the eye-sight cannot really be said to delude us when it seems to tell us that—for example—the moon is as large as the sun. All that sight really tells us is that the sun and the moon occupy fields of view of the same apparent size. This, of course, is correct information as far as it goes, and the sense of sight cannot go further. But the sense of sight conveys false ideas to the mind, sometimes even about apparent size.

Perhaps the most remarkable case of the kind—at any rate the most familiar—is the apparent increase of the sun and moon in size as they approach the horizon. Singularly enough, Professor Le Conte does not regard this as an optical illusion; "the visual angle being in both cases precisely the same, the size of the image on the retina must have been the

same." But one might with equal reason say that none of the illusions relating to touch or heat are really illusions, seeing that the actual effects produced on the nerves of touch correspond with the actual shapes or temperatures of the objects felt. In every case of sense illusion the nerves give correct information, it is the interpretation of the information which is incorrect.

The apparent largeness of the moon near the horizon is of course a real illusion. It is often elaborately explained as due to the magnifying power of the layers of air through which the moon is viewed. In the "Wide Wide World" the overwhelmingly wise John Marchmont explains the matter thus to Ellen Montgomery (I hope my recollection of the names is trustworthy, but the book came out a long while ago, and I have not seen it since its first appearance). But the moon is not magnified at all in *that* sense. She does not occupy a larger space in the visual field. Nay she looks rather smaller when near the horizon, being then nearly 4,000 miles nearer to us than when overhead. It is easy to show this; and in passing I cannot too earnestly recommend those who wish to form correct ideas about the apparent sizes, shapes, positions, and movements of the heavenly bodies, to test such matters in simple ways such as I am about to suggest in the moon's case. Cut out in card a circle exactly half an inch in diameter, leaving a projecting piece of card outside some part of the rim. Then take a straight rod about 54 inches long, and with a tack through the projecting piece fasten the disc at one end of the rod, so that the whole disc is visible from the other end. Now it will be found that if the rod be directed toward the moon, the disc of card at the end furthest from the eye, will just hide the moon from an eye placed at the nearest end. Whether the moon is high up in the sky or close to the horizon the same thing happens. The moon looks just as large high up as she does low down, on any given night. Of course, as the moon's path round the earth is not quite circular there is a change in the moon's apparent size in the course of each lunar month,—a change which the method of measurement just described will serve very well—rough though it is—to indicate. Just as the sun varies in apparent diameter as the year progresses, his diameter on January 1, bearing to his diameter on July 1 the ratio 31 to 30, so the moon varies as the month progresses, and in greater degree. But look at the moon from one end of the rod when she is rising and you will find the card disc at the other end cover her either exactly or very nearly, and when she is at her highest on the same night you will find her as exactly or as nearly covered by the card disc the rod being directed in the same way toward her, and the disc viewed by an eye placed at the other end of the rod.

Here then is an optical illusion by which the idea is conveyed that the moon is larger when low down than she is when high above the horizon, though in reality occupying as large (nay, even a slightly larger) portion of the visual field. It is the same with the sun, and the same also with any one of the familiar star groups which pass from close by the horizon to a great distance above it. How is this deception to be explained?

The increase of the moon's size near the horizon has been attributed to the circumstance that when she is low down we can compare her apparent size with that of known objects near the horizon, and seeing that she looks larger than many objects which are known to be really large, as trees, houses, and so forth, we can judge that she is larger than we had (unconsciously) supposed her to be when high up. But I cannot see that there is any force in this explanation. It is true that if the moon when low down is looked at through a tube of any sort, hiding surrounding objects, she no longer appears so large. But this does not prove that the surrounding objects make her look larger, other

relations besides those depending on the appearance of surrounding objects are concealed by the tube; and amongst them that which is, I take it, the true explanation of the moon's apparent increase of size.

The fact is that the increase in the apparent size of the moon and other celestial objects as they draw nearer to the horizon is connected with a much wider illusion affecting the apparent dome-shape of the sky over our heads.

Of course when we look at a cloud-laden sky we perceive at once that our range of view is not limited by the interior of a hemispherical surface. The region above our heads seems shaped like the interior of a very much flattened dome, the horizon being much farther away than the sky directly overhead. When the sky is clear the dome above us seems more arched, but it never appears like a true hemisphere. Probably to ordinary eye-sight the star-strewn sky on a clear night appears shaped as though the part directly overhead were at only about one-quarter the distance of the part near the horizon. But of course the range of the moon's path around any observer on earth is such that her distance varies very slightly, as if in fact she always moved on the inner surface of a sphere having the observer at its center. To one then who entertains unconsciously the erroneous notion that the sky is arched over the earth, in such sort that the region overhead lies at about a fourth the distance of the horizon, the expectation unconsciously arises that when the moon is close to the horizon she will present a smaller disc than when she is high up in the sky. As a matter of fact, she looks about as large (not quite, but very nearly), that is, she subtends the same visual angle; but the effect of her looking so much larger than had been unconsciously expected, is to suggest that she is really larger than when high above the horizon. We apply to her the same unconscious reasoning by which we recognize that a tree on the horizon which subtends the same apparent angle as a tree close by is much the larger of the two. Having in reality no means of estimating the real size of the moon, we make its apparent position guide us to an idea of its size, and as it seems—being near the horizon—much farther away than when high, yet looks no smaller, we judge it to be really larger.

I had a singular example recently of the effect of position in forcing an illusory idea on the mind, even when the truth was well and even familiarly known. I was in the streets of Charleston (South Carolina) engaged in conversation, but my eyes directed toward the upper ridge of a projecting balcony. While I talked, I saw what looked like a bird's head rising just beyond the ridge, and in a moment or two there was the creature, a tiny but very oddly shaped bird apparently fluttering above the balcony. It looked no larger than a humming-bird. Now I knew at once that I was not looking at a bird, because I could see that the object had a pendent waving tail such as no bird ever had. I knew as well that it was not a small bird close by, but a Chinese kite at a considerable distance, as I knew that it was day; yet because my mind had started with the wrong idea that the object was just above the balcony, I could not for several seconds shake off the absurd impression that there was a miniature bird-kite fluttering above a straight stone ridge where assuredly was no string attached to it. I take it that the deception by which, against my own knowledge, I was for awhile made to imagine the kite much smaller than it really was, because it seemed much nearer than such an object is usually seen, was precisely akin to the illusion by which, against our own knowledge we are led to imagine the moon much enlarged near the horizon because it there seems much farther away than as seen high up toward the zenith.

The illusion as to the shape of the heavens around us and the sky above

us (not the same thing be it noticed) is one which deceives us all the time, —at least I have never met with any-one who has been able to correct either form of illusion. We conceive the heavenly bodies overhead to be nearer to us than those near the horizon, the heavenly concave being presented as somewhat flattened overhead: and on the other hand a cloud-covered sky appears arched overhead instead of having a flat horizontal surface. Do what we will we cannot force the mind to feel either that the stars overhead are no nearer than those by the horizon, or that the clouds near the horizon are as much farther away than those overhead, as they really are. The clouds low down seem somewhat farther away than those above our heads,—perhaps four or five times farther: but in reality they are usually twenty or thirty times farther from us. But the mind refuses to present to us the much greater distance of those low-lying clouds.

It may be said, indeed, that the mind is unable to conceive a spherical surface, either convex or concave, beyond a certain size, which differs probably in the case of each person, differs certainly as life advances, and is far short of the dimensions of any one of the celestial globes, except possibly the moons of Mars. It may be that if living in Fear or Terror (as the attendants on Mars have been called) we might recognize the rotundity of the surface of our home, seeing that probably neither of these moons has a diameter of more than twenty miles. But it is certain that no one can appreciate the rotundity of our earth, in such sort that not merely the circumstance that the globe is rotund is recognized, but the dimensions of the globe of which the region we see at any moment is a part. The best proof of this is found in the fact that the earth's surface appears concave so soon as we see any very large extent of it. As seen from a balloon, for instance, the earth seems like a gigantic basin, the mind not being able to take in the real truth that the earth is too large for the horizon to dip recognizably even when the eye is two or three miles above the earth's surface. If one could pass away from the earth to distances so great that she would be visible as a globe, we should still be unable to form any idea of her size,—just as now the sun, moon, planets, and stars tell the eye nothing of their real dimensions.

A curious question here suggests itself:—Supposing one could pass away from the earth's surface steadily till she appeared like a globe, what would be the changes her aspect would undergo? She would certainly appear concave until a great height had been attained; and as certainly she would eventually appear a globe as the sun and moon do: but in what way, I wonder, would the apparently concave surface pass to a manifestly convex surface? Would this happen gradually, or would the conviction suddenly force itself on the mind that the surface which had appeared concave was really convex? There is a familiar illusion which illustrates such a change as this, and seems to suggest that the change of appearance would be sudden. If you look through a lens, inverting the object seen, at a convex surface, it appears to be concave (a coin under the same conditions appears to have all the parts which are really in relief depressed) because the mind recognizes the evidence given by the shadows without being conscious that this evidence has been inverted by the action of the lens. Now if, while the convex surface thus appears concave you introduce into the field of view some object which shows which way the shadows really fall—as an upright pin, or the like—you find the seeming concavity at once changed to convexity, the mind being unable to note how the change takes place, so rapid is it. Possibly this would be the way in which the seeming concavity of the earth would change to convexity, as we passed away to the distances at which the earth would appear like a celestial orb.

Illusions affecting our ideas about the apparent brightness of objects are even more deceptive than those affecting form. The French astronomer Chacornac wrote an article once in explanation of the superior brightness of the discs of Jupiter and Saturn near the edge. The explanation was ingenious, and would have perhaps thrown light on the nature and condition of the giant planets, if it had only chanced that the superior brightness which he explained had a real existence. As a matter of fact, however, so far are the parts of Jupiter and Saturn near the edge of their discs from being brighter than the parts near the middle that the precise reverse is the case, and in quite a marked degree. I was first led to observe this by theoretical considerations, which seemed to suggest that the light from the parts of Jupiter near the edge ought to be very much less than the light from the middle of the planet's disc. It so chanced that just as I had satisfactorily reasoned this out, I came across Chacornac's article explaining why the edge is so much and so obviously brighter than the middle. This led me to inquire whether the case really was as he supposed or not. Now, to those who have paid attention to the phenomena of Jupiter's satellites, many circumstances are known which show that the edge of Jupiter's disc must be darker than the middle. For example, a satellite looks light when near the edge, dark when on the middle of the disc; or else (which proves the same thing) a satellite is scarcely visible near the edge, being so nearly of the same lustre as the planet, but as it passes on to the brighter central parts of the disc it becomes a dark spot, sometimes even looking as dark as its own shadow close alongside. All this in reality proves that the edge is darker than the middle of the disc; yet it looks decidedly brighter. I suggested, therefore, to a friend who was making experiments on the luminosity of various celestial bodies, that he should test this matter by determining whether the parts of Jupiter's disc near the edge or the parts near the middle remained longest visible when the light of the planet was gradually extinguished by means of a neutral-tinted darkening glass (graduated from almost complete transparency at one hand to almost complete opacity at the other). The result was decisive, and exactly contrary to the evidence of the eyes. The parts which to the eye seemed so obviously the brightest were the first to yield to the absorption of the light, the parts which looked least bright remained visible longest. Of course, the illusion is easily explained. By contrast with the black background of the sky the parts near the edge of Jupiter and Saturn look brighter than they really are.

A noteworthy illusion was passingly indicated in what I have just described. I have said that a satellite sometimes looks as dark as its shadow close alongside. Now the shadows of the satellites look black; but the satellite itself cannot be black. We see then that the appearance of blackness does not necessarily imply real blackness. So the spots on the sun look black near the middle of the umbra; yet they cannot be really black there; and indeed when examined so that the effect of contrast is avoided they are found to emit a considerable amount of light. Another case of illusion may be noticed in total eclipses of the sun. Here the body of the moon looks black; yet in reality it is lit up at least twelve times as brightly as a landscape under full moonlight, for the earth is at the time of solar eclipse shining full upon the half of the moon turned earthwards, and her disc is 13½ times as large as the moon's appears to us. To my mind, one of the best proofs of the brightness of the solar corona, is found in the seeming blackness of the moon's disc during total solar eclipse.

But the seeming whiteness of the moon's disc when she is full is quite as much an illusion as its seeming blackness when she is between the

sun and us. For the moon is not really white. She is much more nearly black. Regarding 100 as representing perfect whiteness, the average tint of the moon's surface would be represented by only 17. Probably the darker portions, which, when she is full look only slightly less white than the rest, are as dark as our porphyries and syenites.

Another remarkable illusion affecting brightness is that which has deceived several students of the moon in the case of the floor of the lunar crater, Plato. This broad expanse seems to grow darker as the sun rises higher above its level; but this is a pure illusion, due to the gradual diminution of the black shadows of the surrounding mountains. By contrast with these shadows the floor looks lighter than it really is; as they diminish it seems to grow darker; when they disappear altogether it looks darkest; and as they gradually grow larger in the afternoon and evening of the long lunar day there, the floor seems to get light again. As a matter of fact the floor gets brighter as the sun rises higher above its level, and darkens again as the sun gradually nears the horizon of Plato.

The illusions affecting motion are too remarkable and too numerous to be dealt with properly in the small space remaining to me here. I may, perhaps, consider them hereafter in a separate short essay.

ANIMALS OF THE PRESENT AND THE PAST.

Mr. Grant Allen (for to his facile pen the article on "Big Animals," in a recent number of the *Cornhill Magazine* may safely be attributed), has done good service in showing how unfounded are two very prevalent ideas respecting the past of this earth on which we live—viz., first, the idea that the various races of animals which appear in the geologic record all existed at some remote time ("in those days," meaning some imaginary epoch specially belonging to geological science); and secondly, the idea that in past ages the animals existing on the earth were very much larger than those now known.

As regards the first idea, relating to geological time, the Pleistocene age is really as yesterday in the past history of our earth, and the Pliocene as the day before yesterday. The mammoth in the northern hemisphere, and the moa in the southern, are creatures of yesterday, while the mastodon, on the same time scale, can be set no further back than the last generation or so. On the other hand, the "monstrous" marine saurians of the Jurassic era are of remote antiquity. Mr. Allen expresses the relation, in point of time, neatly, when he says that "to compare the relative lapses of time with human chronology, the mastodon stands to our own fauna as Beau Brummel stands to the modern masher, while the saurians stand to it as the Egyptian and Assyrian warriors stand to Lord Wolseley and the followers of the Mahdi." In fact, the mind, as regards its power of dealing with time-intervals, is lost in the presence of the vastness of the era to which our own period belongs as compared with the minute span over which history extends its survey—is lost, yet once more, in comparing even with the vastness of the glacial period the seemingly immeasurable duration of the Pliocene and its still longer predecessor the Miocene, and, endeavoring to look beyond these into still remoter depths of past time, is simply appalled. The Eocene was so long-lasting, that the sequent eras, which with it make up the Tertiary period, seem by comparison as seconds compared with hours. But the whole duration of the Tertiary period is insignificant compared with the inconceivable length of the Secondary period, while the Secondary period, in turn, is short compared with the Primary period, and even this tells us only of the close of a yet more tremendous time-interval, during which

no trace was left of the earth's progress to the world form, any more than the sea leaves any record of the progress of the storms which sweep over its vast surface.

Truly it is amazing to consider now, when these vast periods of time have taken their place among the recognized and assured teachings of the great earth volume, that but half a century or so ago a struggle was still maintained to reduce our estimate of the earth's past existence to a few thousands of years, while multitudes of well-meaning persons imagined that an eternity of future happiness or misery depended on each man's rejection or acceptance of the doctrine which God's work, the earth, assuredly teaches. Yet, strangely enough, the school of those who maintained that hopeless struggle is not ashamed even now to denounce the followers of the scientific school for accepting the obvious meaning of these new pages of that great volume which have since been turned over.

With regard to the dimensions of the modern inhabitants of the earth, we must remember that to every era of the earth's history a special kind of development has been specially appropriate. It is certain that the great land monsters of the Jurassic age could not exist now. For while their numbers must have always been limited, even when surrounding conditions favored their existence, the powers of the human race at the present time would be fatal to the existence of these unwieldy monsters. The monstrous eft, which of old was lord and master of earth, might maintain, at least for awhile, the position of lord and monarch still, were it not for man. But with man in the arena against the Atlantosaurus, one or other would have to give way, and it would not be man. The mammals of the Pliocene age were not so much greater than their modern representatives that we need consider them specially. And assuredly when we turn to the sea-monsters of our own time we need not fear comparison with even the mightiest monsters of past geological ages. The Rorqual attains sometimes to a length of fully one hundred feet, the razor-back whale sometimes measures seventy feet, and there are other cetaceans not much inferior in size. As to the dimensions of sharks, some doubt appears to exist. Considering the nature of the creature, and that men have never found it desirable to hunt for sharks as they have for whales (possibly if they had they would have made but unsatisfactory progress in the art of shark-hunting), it would be absurd to suppose that we have become acquainted even with the largest existing varieties, far less with the largest individual specimens. To give an idea of the state of things in regard to sharks, I may record an experience of my own. In the voyage from Auckland, N. Z., to Honolulu, the *City of Sydney* was temporarily disabled by the breaking of a crank-pin. Up to the day when this accident occurred, not one among the crew or passengers had seen a single shark of any kind, though the passengers certainly passed a good half of their time looking at the waters around them. But scarcely had we been at rest a quarter of an hour before the sea all around our disabled ship was literally swarming with sharks. When I learn, therefore, that the naturalists of the *Challenger* expedition have dredged up in numbers from the ooze of the Pacific shark teeth five inches long by four wide, which would indicate that the sharks to which these teeth belonged were a hundred feet long, I feel no doubt that sharks of these dimensions are still in existence. Dr. Günter, of the British Museum, writes, it is true, that "as we have no record of living individuals of that bulk, the gigantic species to which the teeth belonged must probably have become extinct within a comparatively recent period." And Mr. Grant Allen speaks of him as a very cautious naturalist for thus avoid-

ing the natural conclusion that the species is not extinct at all. But to my mind it savors of much greater daring to imagine the extinction than the existence of these gigantic carcharodons. We know of nothing which could probably have led to the extinction of monsters such as these, which would have all their own way among the denizens of the great deep. Man has not sought their destruction as he has sought the destruction of species of whales which nevertheless still exist; they cannot have been attacked and destroyed by other species of fish, or even conceivably deprived of the means of living by more active and predaceous creatures. That they should die out, then, seems altogether unlikely; whereas it is altogether natural that they should remain unknown amid the depths of the mighty ocean, for they would keep to the great deep, avoiding even an approach to shallows, nor would they be apt to show where the smaller and more numerous orders of sharks are seen.

Albeit I may remark that Mr. Allen seems to me mistaken in assuming that the monstrous sharks to whom these teeth belonged were as large as any sea creatures of remote geological eras. I have in my possession shark's teeth collected in the neighborhood of Charleston, S. C., which are 5½ in. long by 4½ in. broad, and in the Museum of Charleston they have shark's teeth much larger even than that.

The largest calamaries of the present time are certainly larger than any of those whose remains exist as fossils. A cuttle thrown up on the shore of Newfoundland was 80 ft. long.

On the whole, it may be doubted whether at any time in the past history of the earth the average size of the ten largest creatures by sea and land exceeded the average size of the ten largest species existing at the present day.—*Newcastle Weekly Chronicle.*

LIFE IN OTHER WORLDS.

So far back as 1869, I had begun to regard doubtfully the theory that all the planets are the abode of life. The careful study of the planets Jupiter and Saturn had shown that any such theory regarding these planets is altogether untenable. The great difference between them and the members of the smaller planetary family of which our earth is the chief, suggested that in truth the major planets belong to another order of orbs altogether, and that we have as much or as little reason for comparing them to the sun as for comparing them to the earth on which we live. Nevertheless, in the case of Venus and Mars, the features of resemblance to our earth predominate over those of dissimilarity; and it was natural that, while rejecting the theory of life in Jupiter or Saturn as opposed to all the available evidence, I should still consider the theory of life in Mars or Venus as at least plausible. Ideas on such subjects are not less tenacious than theories on matters more strictly scientific. Not only so, but the bearing of newly-recognized facts on long-entertained theories is not at once recognized even by those most careful to square their opinions according to the evidence they are acquainted with. Again and again it has happened that students of science (in which term I include the leaders of scientific opinions) have been found recording and explaining in one chapter some newly-recognized fact, while in another chapter they have described with approval some old theory, in total forgetfulness of the fact that with the new discovery the old theory has become altogether untenable. Sometimes the incongruity is not recognized until it has been pointed out by others. Sometimes so thoroughly do our prepossessions become "bone of our bone and flesh of our flesh" that even the clearest reasoning does not prevent the student of science from combining the

acceptance of a newly-discovered fact with continued belief in a theory which that fact entirely disproves. Let the matter be explained as it may, it was only gradually that both the Brewsterian and Whewellite theories of life in other worlds gave place in my mind to a theory in one sense intermediate to them, in another sense opposed to both, which seems to accord better than either with what we know about our own earth, about the other members of the solar system, and about other suns which people space. What I now propose to do is to present this theory as specially illustrated by the two planets which now adorn our skies at night, and by the ruddy but at present invisible Mars.

But it may be asked at the outset, whether the question of life in other worlds is worthy of the attention thus directed to it. Seeing that we have not and can never have positive knowledge on the subject, is it to be regarded as, in the scientific sense, worthy of discussion at all ? Can the astronomer or the geologist, the physicist or the biologist, know more on this subject than those who have no special knowledge of astronomy, or geology, or physics, or biology? The astronomer can say how large such and such a planet is, its average density, the length of its day and its year, the light-reflecting qualities of its surface, even (with the physicists' aid) the nature of the atmosphere surrounding it, and so on ; the geologists can tell much about the past history of our own earth, whence we may infer the variations of condition which other earths in the universe probably undergo ; the physicist, besides aiding the astronomer in his inquiries into the condition of other orbs, can determine somewhat respecting the physical requirements of living creatures ; and the biologist can show how the races inhabiting our earth have gradually become modified in accordance with the varying conditions surrounding them, how certain ill-adapted races have died out while well-adapted races have thriven and multiplied, and how matters have so proceeded that during the whole time since life began upon our earth there has been no danger of the disappearance of any of the leading orders of living creatures. But no astronomer, or geologist, or physicist, or biologist, can tell us anything certain about life in other worlds. If a man possessed the fullest knowledge of all the leading branches of scientific research, he would remain perfectly ignorant of the actual state of affairs in the planets even of our own system. His ideas about other worlds must still be speculative ; and the most ignorant can speculate on such matters as freely as the most learned. Indeed, the ignorant can speculate a great deal more freely. And it is *here*, precisely, that knowledge has the advantage. The student of science feels that in such matters he must be guided by the analogies which have been already brought to his knowledge. If he rejects the Brewsterian or the Whewellite theory, it is not because either theory is a mere speculation for which he feels free to substitute a speculation of his own ; but because, on a careful consideration of the facts, he finds that the analogies on which both theories were based were either insufficient, or were not correctly dealt with, and that other analogies, or these when rightly viewed, point to a different conclusion as more probable.

Nor need we be concerned by the consideration that there can be no scientific value in any conclusion to which we may be led on the subject of life in other worlds, even though our method of reasoning be so far scientific that the argument from analogy is correctiy dealt with. If we look closely into the matter, we shall find that as respects the great purposes for which science is studied, it is as instructive to think over the question of life in other worlds as to reason about matters which are commonly regarded as purely scientific. It is scientific to infer from observations

of a planet that it has such and such a diameter, or such and such a mass; and thence to infer that its surface contains so many millions of square miles, its volumes so many millions of cubic miles, its mass so many billions or trillions of tons; yet these facts are not impressive in themselves. It is only when we consider them in connection with what we know about our own earth that they acquire meaning, or, at least, that they have any real interest for us. For then alone do we recognize their bearing on the great problem which underlies all science,—the question of the meaning of the wonderful machinery at work around us; machinery of which we are ourselves a portion.*

In suggesting views respecting Jupiter and Mars unlike those which have been commonly received with favor, it is not by any means my purpose, as the reader might anticipate, to depart from the usual course, of judging the unknown by the known. Although that course is fraught with difficulties, and has often led the student of science astray, it is in such inquiries as the present the proper, one may almost say the only, course. The exception I take to the ordinary views is not based on the fact that too much reliance has been placed on the argument from analogy, but that the argument has been incorrectly employed. A just use of the argument leads to conclusions very different from those commonly accepted, but not less different from that theory of the universe to which Whewell seems to have felt himself driven by his recognition of the illogical nature of the ordinary theory respecting the plurality of worlds.

Let us consider what the argument from analogy really teaches us in this case.

The just use of the argument from analogy requires that we should form our opinion respecting the other planets, chiefly by considering the lessons taught us by our own earth, the only planet we are acquainted with. Indeed, it has been thus that the belief in many inhabited worlds has been supported; so that if we employ the evidence given by our own earth, we cannot be said to adopt a novel method of reasoning, though we may be led to novel conclusions.

The fact that the earth is inhabited, affords, of course, an argument in favor of the theory that the other planets are also inhabited. In other words a certain degree of probability is given to this theory. But we must look somewhat more closely into the matter to ascertain what the probability may amount to. For there are all orders of probability, from certainty down to a degree of probability so low that it approaches closely to that extremest form of improbability, which we call impossibility. It is well at once to take this logical basis; for there are few mistakes more mischievous than the supposition that a theory supported by certain evidence derives from that evidence a probability equal to that of the evidence itself. It is absolutely certain that the one planet we know is inhabited; but it by no means follows certainly that planets like the earth support life, still less that planets unlike the earth do so, and least of all that every planet is now the abode of life.

A higher degree of probability in favor of the theory that there are many inhabited worlds arises from a

* It has often seemed to us that a description, by the close observer Dickens, of the fancies of a brain distempered by fever, corresponds with feelings which the student of science is apt to experience as the sense of the awful mystery of the universe impresses itself on his soul:—"The time seemed interminable. I compounded impossible existences with my own identity. . . . I was as a steel beam of a vast engine, clashing and whirling over a gulf, and yet I implored in my own person to have the engine stopped, and my part in it hammered off." Of all the wonders that the student of science deals with, of all the mysteries that perplex him, is there aught more wonderful, more perplexing than the thought that he, a part of the mighty machinery of the universe, should anxiously inquire into its nature and motions, should seek to interpret the design of its Maker, and should be concerned as to his own share in the working of the mysterious mechanism?

consideration of the *manner* in which life exists on the earth. If one could judge of a *purpose* (according to our way of thinking) in all that is going on around us, our earth might teach us to regard the support of life as Nature's great purpose. Earth, water, and air alike teem with life. No peculiarities of life seem able to banish life. As I have said elsewhere, "in the bitter cold within the Arctic regions, with their strange alternations of long summer days and long winter nights, their frozen seas, perennial ice, and scanty vegetation, life flourishes in a hundred different forms. On the other hand, the torrid zone, with its blazing heat, its long-continued droughts, its strange absence of true seasonal changes, and its trying alternations of oppressive calms and fiercely-raging hurricanes, nourishes even more numerous and varied forms of life than the great temperate zones. Around mountain summits as in the depths of the most secluded valleys, in mid-ocean as in the arid desert, in the air as beneath the surface of the earth, we find a myriad forms of life." Nor is the scene changed when, with the mind's eye, we contemplate the earth during past ages of her history, even to the most remote stage of her existence as a planet fit to be the abode of life. Whenever there was life at all, there was abundant life. For, though no traces remain of a million forms of life which co-existed with the few forms recognized as belonging to this or that geologic era, yet we can infer from the forms of which traces remain that others must have been present which have left no trace of their existence. The skeletons of mighty carnivora assure us that multitudes of creatures existed on which those monsters fed. The great sea-creatures whose remains have been found, attest the existence of many races of small fish. The mighty Pterodactyl did not range through desert aërial regions, for he could exist only where many orders of aërial creatures also existed. Of minute creatures inhabiting the water we have records in the strata formed as generation after generation sank to the sea bottom after death, whereas the correspondingly minute inhabitants of the land and of the air have left no trace of their existence; yet we can feel no reasonable doubt that in every geologic age, forms of minute life were as rich in air and on the land as in the sea, or as they now are in all three. Of insect life all but a few traces have passed away, though occasionally, by some rare accident, even so delicate a structure as a butterfly's wing has left its record, not only attesting the existence of hosts of insects, but showing that delicate flowers, with all the charms of sweet perfume and variegated color, existed in those times as in ours. It is no mere speculation, then, but the direct and unquestionable teaching of geology, that throughout the whole time represented by the fossiliferous rocks, life of all kinds was most abundant on our earth.

And while we thus recognize throughout our earth's history as a planet, Nature's apparent purpose of providing infinitely varied forms of life at all times and under the most varied conditions, we also perceive that Nature possesses a power of modifying the different types in accordance with the varying conditions under which they subsist. Without entering here into the vexed question of the actual extent to which the principle of selection operates, we must admit that it does operate largely, and that it must necessarily cause gradual change of every type of living creature toward the most suitable form. This particular operation of Nature must certainly be regarded as an apparent carrying out of the purpose attributed to her,—by our manner of speaking when we say that Nature's one great object is the support of life. If types were unchangeable, life would come to an end upon a globe whose condition is not only not unchangeable, but changes largely in the course of long periods of time.

But types of life change, or can change when required, at least as quickly as the surrounding conditions—save in the case of certain catastrophes, which, however, never affect any considerable proportion of the earth's surface.

Nor is it easy to assign any limits to this power of adaptation, though we can scarcely doubt that limits exist. The earth may so change in the course of hundreds of thousands of years to come that none of the chief forms of life, animal or vegetable, at present existing, could live even for a single year under the changed conditions of those distant times, while yet the descendants of creatures now living (including man) may be as well fitted to the circumstances around them as the most favored races of our own time. Still there must be a limit beyond which the change of the earth's condition, whether through the cooling of her own globe or the diminution of the sun's heat, will be such that no conceivable modification of the types of life now existing could render life possible. It must not be forgotten that Nature's power of adaptation is known to be finite in many cases, and therefore must be presumed to be finite in all cases. The very process of selection by which adaptation is secured implies the continual failure of preceding adaptations. The struggle for life involves the repeated victory of death. The individuals which perish in the struggle (that is, which perish untimely) far outnumber those which survive. And what is true of individuals is true of types. Nature is as wasteful of types as she is of life—

> So careful of the type; but no,
> From scarped cliff and quarried stone
> She cries "a thousand types are gone;
> I care for nothing, *all* shall go."

This is, in truth, what we must believe, if, reasoning by analogy, we pass but one step higher in the scheme of creation. We know that Nature, wasteful of individual life, is equally wasteful of types of life. Must we not infer that she is no less wasteful of those aggregations of types which constitute the populations of worlds? Watching her operations a few brief minutes, we might (setting experience aside) suppose her careful of individual life. Watching during a few generations, we should pronounce her careful of the type, though careless of individual life. But we perceive, when we extend the range of time through which we look, that she is careless no less of the type than of life. Why should this extension of the range of view be the last we should permit ourselves? If we pronounce Nature careful of the planetary populations, though careless of the types of life which make up such populations, we are simply declining to take a further step in the course pointed out for us by the teachings of analogy.

Let us go over the ground afresh. Individual creatures, even the most favored, perish after a time, though the balance may long oscillate between life and death. Weak, at first, each creature which is to live grows at length to its full strength, not without vicissitudes which threaten its existence. As its life progresses the struggle continues. At one time the causes tending to decay seem to prevail a while; at another, those which restore the vital powers. Disease is resisted again and again; at first easily, gradually with greater difficulty, until at length death wins the day. So it is with types or orders of living creatures. A favored type, weak at first, begins after a while to thrive, and eventually attains its fullest development. But from time to time the type is threatened by dangers. Surrounding conditions become less favorable. It ceases to thrive, or, perhaps, passes through successive alternations of decay and restoration. At length the time comes when the struggle for existence can manifestly have but one end; and then, though the type may linger long before it actually disappears, its

disappearance is only a question of time. Now, it is true that each type thus flourishing for a while springs from other types which have disappeared. The favored types of our age are but varieties of past types. Yet this does not show that types will continue to succeed each other in endless succession. For, if we consider the matter rightly, we perceive that the analogue of this circumstance is, in the case of individual life, the succession of living creatures generation after generation. And as we know that each family, however large, dies out in the long run unless recruited from without, so we are to infer that the various types peopling this earth, since they cannot be recruited from without, must at length die out, though to our conceptions the time necessary for this process may appear infinite.

To the student of science who recognizes the true meaning of the doctrine that force can be neither annihilated nor created, it will indeed appear manifest that life must eventually perish from the face of the earth; for he perceives that the earth possesses now a certain fund or store of force in her inherent heat, which is continually though slowly passing away. The sun also, which is a store-house whence certain forms of force are distributed to the earth, has only a finite amount of energy (though probably the inhabitants of the earth are less directly concerned in this than in the finiteness of terrestrial forces). Life of all kinds on the earth depends on both these stores of force, and when either store is exhausted life must disappear from the earth. But each store is in its nature limited, and must one day, therefore, be exhausted.

We have also only to consider that life on the earth necessarily had a beginning to infer that it must necessarily have an end. Clearest evidence shows how our earth was once "a fluid haze of light," and how for countless æons afterwards her globe was instinct with fiery heat, amidst which no form of life could be conceived to exist, after the manner of life known to us, though the germs of life may have been present "in the midst of the fire." Then followed ages in which the earth's glowing crust was drenched by showers of muriatic, nitric, and sulphuric acid, not only intensely hot, but fiercely burning through their chemical activity. Only after periods infinite to our conceptions could life such as we know it, or even in the remotest degree like what is now known to us, have begun to exist upon the earth.

The reader, doubtless, perceives whither these considerations tend, and how they bear in an especial manner on the opinion we are to form respecting such planets as Jupiter and Saturn on the one hand and Mars on the other. We see our earth passing through a vast period, from its first existence as a separate member of the solar system, to the time when life appeared upon its surface: then began a comparatively short period, now in progress, during which the earth has been and will be the abode of life; and after that must follow a period infinite to our conceptions when the cold and inert globe of the earth will circle as lifelessly round the sun as the moon now does. We may, if we please, infer this from analogy, seeing that the duration of life is always infinitely small by comparison with the duration of the region where life appears; so that, by analogy, the duration of life on the earth would be infinitely short compared with the duration of the earth itself. But we are brought to the same conclusion independently of analogy, perceiving that the fire of the earth's youth and the deathly cold of her old age must alike be infinite in duration compared with her period of vital life-preserving warmth. And what is true of the earth is true of every member of the solar system, major planet, minor planet, asteroid, or satellite; probably of every orb in space, from

the minutest meteorite, to suns exceeding our sun a thousandfold in volume.

If we had any reason to suppose that all the planets sprang simultaneously into being, that each stage of each planet's existence synchronized with the same stage for every other planet, and that life appeared and disappeared at corresponding stages in the existence of every planet, we should be compelled to accept the theory that at this moment every planet is the abode of life. Not only, however, have we no reason to suppose that any one of these conditions exists (and not one but *all* these conditions must exist before that theory can be accepted), but we have the strongest possible evidence, short of actual demonstration, that the births of the different planets occurred at widely remote periods, and that the several stages of the different planets' growth differed enormously in duration ; while analogy, the only available evidence on the third point, assures us that little resemblance can be supposed to exist between the conditions and requirements of life in different members of the solar system.

On any reasonable hypothesis of the evolution of the solar system, the eight primary planets must have begun to exist as independent bodies at very different periods. If we adopt Laplace's theory of the gradual contraction of a mighty nebula, then we should infer that the planets were formed in the order of their distances from the sun, the remoter planets being those formed first. And according to the conditions of Laplace's hypothesis, the interval separating the formation of one planet from that of its next neighbor on either side must have been of enormous duration. If we prefer the theory of the gradual growth of each planet by processes of accretion, we should infer perhaps that the larger planets took longest in growing to maturity, or preferably that (according to the doctrine of probabilities) a process which for the whole system must have been of inconceivably enormous length, and in which the formation of one planet was in no sort connected with the formation of any other, could not have resulted in bringing any two planets to maturity at the same or nearly the same time, save by so improbable a combination of fortuitous circumstances as may justly be considered impossible. If we consider that the solar system was evolved by a combination of both processes (the most probable theory of the three in my opinion), we must still conclude that the epochs of the formation of the different planets were separated by time-intervals so enormous that the duration of life upon our earth is, by comparison, as a mere second compared with a thousand years.

Again, if we compare any two members of the solar system, except, perhaps Venus and the Earth, we cannot doubt that the duration of any given stage of the existence of one must be very different from that of the corresponding stage in the other. If we compare, for instance, Mars with the Earth, or the Earth with Jupiter, and still more, if we compare Mars with Jupiter, we cannot doubt that the smaller orb of each pair must pass much more rapidly through the different stages of its existence than the larger. The laws of physics assure us of this, apart from all evidence afforded by actual observation ; but the results of observation confirm the theoretical conclusions deduced from physical laws. We cannot, indeed, study Mars in such sort as to ascertain his actual physical condition. We know that his surface is divided into lands and seas, and that he possesses an atmosphere; we know that the vapor of water is at times present in this atmosphere; we can see that snows gather over his polar regions in winter and diminish in summer : but we cannot certainly determine whether his oceans are like our own, or for the most part frozen ; the whitish light which spreads at times over land or sea may be due to

clouds or to light snow-falls, for aught that observation shows us; the atmosphere may be as dense as our own or exceedingly rare; the polar regions of the planet may resemble the earth's polar regions, or may be whitened by snows relatively quite insignificant in quantity. In fine, so far as observation extends, the physical condition of Mars may closely resemble that of the earth, or be utterly dissimilar. But we have indirect observational means of determining the probable condition of a planet smaller than the earth, and presumably older —that is, at a later stage of its existence. For the moon is such a planet, and the telescope shows us that the moon in her decrepitude is oceanless, and is either wholly without atmosphere or possesses an atmosphere of exceeding tenuity. Hence we infer that Mars, which, as an exterior planet, and much smaller than the earth, is probably at a far later stage of its existence, has passed far on its way toward the same state of decrepitude as the moon. As to Jupiter, though he is so much farther from us than Mars, we have direct observational evidence, because of the vast scale on which all the processes in progress on his mighty globe are taking place. We see that his whole surface is enwrapped in cloud-layers of enormous depth, and undergoing changes which imply an intense activity (or, in other words, an intense heat) throughout his whole mass. We recognize in the planet's appearance the signs of as near an approach to the conditions of the earth when as yet the greater part of her mass was vaporous, as is consistent with the vast difference necessarily existing between two orbs containing such unequal quantities of matter.

Mars, on the one hand, differs from the earth in being a far older planet —*probably*, as respects the actual time which has elapsed since the planet was formed, and *certainly* as respects the stage of its career which it has now reached. Jupiter, on the other hand, differs from the earth in being a far younger planet—not in years perhaps, but in condition. As to the actual age of Jupiter we cannot form so probable an opinion as in the case of Mars. Mars being an exterior planet, must have *begun* to be formed long before the earth and being a much smaller planet, was probably a shorter time in attaining its mature growth. On both accounts, therefore, he would be much older than the earth in years; while, as we have seen, his relative smallness would cause the successive stages of his career subsequent to his existence as an independent and mature planet to be much shorter. Jupiter, being exterior to Mars, presumably began to be formed millions of centuries before that planet, but his bulk and mass so enormously exceed those of Mars, that his growth must have required a far longer time; so that it is not at all certain that even in point of years Jupiter (dating from his maturity) may not be the youngest member of the solar system. But even if not, it is practically certain that, as regards development, Jupiter is far younger than any member of the solar system, save perhaps his brother-giant Saturn, whose greater antiquity and inferior mass (both suggesting a later stage of development) may have been counterbalanced by a comparative sluggishness of growth in the outer parts of the solar domain.

It is manifest from observed facts, in the case of Jupiter, that he is as yet far removed from the life-bearing stage of planetary existence, and theoretical considerations point to the same conclusion. In the case of Mars, theoretical considerations render it extremely probable that he has long since passed the life-bearing stage, and observed facts, though, they do not afford strong evidence in favor of this conclusion, suggest nothing which, rightly considered, is opposed to it. It is true that, as we have shown in former essays on this planet, Mars presents many features of resemblance to our earth. This

planet rotates in a period not differing much from our day; his year does not exceed ours so greatly as to suggest relations unpleasantly affecting living creatures; it has been shown that there are oceans on Mars, though it is not quite so clear that they are not for the most part frozen; he has an atmosphere, and the vapor of water is at times present in that atmosphere as in ours; clouds form there; snow falls, and perhaps rain from time to time; ice and snow gather at the poles in winter, and are partially melted in summer; the land surface must necessarily be uneven, seeing that the very existence of continents and oceans implies that once, at any rate, the globe of Mars was subjected to forces resembling those which have produced the irregularities of the earth's surface; glacial action must still be going on there, even if there is no rain-fall, and therefore no denuding action corresponding to that which results from the fall of rain on our terrestrial continents. But it is a mistake (and a mistake too commonly made) to suppose that the continuance of those natural processes which are advantageous to living creatures, implies the existence of such creatures. The assumption is that the beneficent processes of nature are never wasted according to our conceptions. Yet we see over and over again in nature not merely what resembles waste, what in fact *is* waste according to our ideas, but an enormous excess of wasted over utilized processes. The sun pours forth on all sides the supplies of light and heat which, where received as on our earth, sustain vegetable and animal life; but the portion received by our earth is less than the 2000 millionth, the portion received by all the planets less than the 230 millionth part, of the total force thus continually expended. And this is typical of nature's operations everywhere. The earth on which we live illustrates the truth as clearly as the sun. We are apt to say that it teems with life, forgetting that the region occupied by living creatures of all orders is a mere shell, while the whole interior mass of the earth, far larger in volume, and undergoing far more active processes of change—teeming, in fact, with energy—contains no living creature, or at least can only be supposed to contain living creatures by imagining conditions of life utterly different from those we are familiar with.

The mere continuance, therefore, on Mars of processes which on the earth we associate with the existence of life, in reality proves nothing as to the continued existence of life on Mars. The surface of the moon, for example, must undergo disturbances,—mighty throes, as the great wave of sun-distributed heat circles round her orb once in each lunation,—yet few suppose that there is life, or has been for untold ages, on the once teeming surface of our companion planet. The formation of Mars as a planet must so long have preceded that of our earth, his original heat must have been so much less, his small globe must have parted with such heat as it once had so much more rapidly, Mars lies so much farther from the sun than our earth does, his atmosphere is so much rarer, his supply of water (the temperature-conserving element) is relatively as well as absolutely so much smaller, that his surface must be utterly unfit to support life in the remotest degree resembling the forms of life known on earth (save, of course, those lower forms which from the outset we have left out of consideration). Yet at one time, a period infinitely remote according to our conceptions of time, the globe of Mars must have resembled our earth's in warmth, and in being disturbed by the internal forces which cause that continual remodeling of a planet's surface without which life must soon pass away. Again, in that remote period the sun himself was appreciably younger; for we must remember that although, measured by ordinary time-intervals, the sun seems to give forth an unvarying supply of heat day by day, a real

process of exhaustion is in progress *there* also. At one time there must have existed on Mars as near an approach to the present condition of our earth, or rather to her general condition during this life-supporting era of her existence, as is consistent with the difference in the surface gravity of the planets, and with other differences inherent as it were in their nature. Since Mars must also have passed through the fiery stage of planetary life, and through that intermediate period when, as it would seem, life springs spontaneously into being under the operation of natural laws not as yet understood by us, we cannot doubt that when his globe was thus fit for the support of life, life existed upon it. Thus for a season,—enormously long compared with our ordinary time-measures, but very short compared with the life-supporting era of our earth's career,—Mars was a world like our own, filled with various forms of life. Doubtless, these forms changed as the conditions around them changed, advancing or retrograding as the conditions were favorable or the reverse, perhaps developing into forms corresponding to the various races of men in possession of reasoning powers, but possibly only attaining to the lower attributes of consciousness when the development of life on Mars was at its highest, thenceforth passing by slow degrees into lower types as the old age of Mars approached, and finally perishing as cold and death seized the planet for their prey.

In the case of Jupiter, we are guided by observed facts to the conclusion that ages must elapse before life can be possible. Theory tells us that this mighty planet, exceeding the earth three hundred times in mass, and containing five-sevenths of the mass of the whole system of bodies traveling around the sun, must still retain a large portion of its original heat, even if we suppose its giant orb took no longer in fashioning than the small globe of our earth. Theory tells us, moreover, that so vast a globe could not possibly have so small a density (less than one fourth the earth's) under the mighty compressing force of its own gravity, unless some still more potent cause were at work to resist that tremendous compression—and this force can be looked for nowhere but in the intense heat of the planet's whole mass. But observation shows us also that Jupiter is thus heated. For we see that the planet is surrounded by great cloud-belts such as our own sun would be incompetent to raise,—far more so the small sun which would be seen in the skies of Jupiter if already a firmament had been set "in the midst of the waters." We see that these belts undergo marvelous changes of shape and color, implying the action of exceeding energetic forces. We know from observation that the region in which the cloud-bands form is exceedingly deep, even if the innermost region to which the telescope penetrates is the true surface of the planet—while there is reason for doubting whether there may not be cloud-layer within cloud-layer, to a depth of many thousand miles,—or even whether the planet has any real surface at all. And, knowing from the study of the earth's crust that for long ages the whole mass of our globe was in a state of fiery heat, while a yet longer period preceded this when the earth's globe was vaporous, we infer from analogy that Jupiter is passing, though far more slowly, through stages of his existence corresponding with terrestrial eras long anterior to the appearance of life upon the scene.

We must, then, in the case of Jupiter, look to a far distant future for the period of the planet's existence as a life-sustainer. The intense heat of the planet must in course of time be gradually radiated away into space, until at length the time will come when life will be possible. Then, doubtless, will follow a period (far longer than the life-sustaining portion of the earth's existence) during which Jupiter will in his turn be the abode of life. It may be that before then

the sun will have lost so large a proportion of heat that life in Jupiter will be mainly sustained by the planet's inherent heat. But more probably the changes in the sun's heat take place far more slowly than the changes in the condition of any planet, even the largest. Possibly, even, the epoch when Jupiter will be a fit abode for life, will be so remote that the sun's fires will have been recruited by the indrawing of the interior family of planets. For it must be remembered that the periods we have to deal with in considering the cooling of such an orb as Jupiter are so enormous, that not merely the ordinary time-measures, but even the vast periods dealt with by geologists must be insignificant by comparison. Yonder is Jupiter still enwrapped in clouds of vapor raised by his internal heat, still seething, as it were, in his primeval fires, though the earth has passed through all the first stages of her existence, and has even long since passed the time of her maturity as a life-sustaining globe. It is no mere fancy to say that all the eras of Jupiter's existence must be far longer than the corresponding terrestrial eras, since we actually see Jupiter in that early stage of his existence and know that the earth has passed through many stages toward the final eras of decay and death. It is, indeed impossible to form any opinion as to the probable condition of the sun or of the solar system when Jupiter shall become fit to support life, seeing that, for aught we know, far higher cycles than those measured by the planetary motions may be passed ere that time arrives. The sun may not be a solitary star but a member of a star-system, and before Jupiter has cooled down to the life-sustaining condition, the sun's relation to other suns of his own system may have altered materially, although no perceptible changes have occurred during the relatively minute period (a trifle of four thousand years or so) since astronomy began.

In considering the case of Mars, I suggested the possibility that owing to the relative shortness of that planet's life-sustaining era, the development of the higher forms of life may have been less complete than on our earth thus far (still less than the development of those forms on the earth in the coming ages). We may well believe that during the long period of Jupiter's existence as a life-supporting planet, creatures far higher in the scale of being than any that have inhabited, or may hereafter inhabit, the earth, will be brought into existence. As the rule of nature on earth has been to advance from simple to more complex forms, from lower types to higher, so (following the argument from analogy) we must suppose the law of nature to be elsewhere. And time being a necessary element in any process of natural development, it follows that where nature is allowed a longer time to operate, higher forms, nobler types, will be developed. If this be so, then in Jupiter, the prince of planets, higher forms of animated conscious being will doubtless be developed than in any other planet. We need not, indeed, point out that the supposition on which this conclusion rests is merely speculative, and that now, when the laws of natural development have so recently begun to be recognized and are still so imperfectly known, the argument from analogy is (in this particular case) necessarily weak. Nevertheless, analogy points in the direction we have indicated, and it is well to look outward and onward in that direction, even though the objects within the view are too remote for us to perceive their real forms.

But, limiting our conclusions to those which may be justly inferred from known facts, let us inquire how the subject of life in other worlds presents itself when dealt with according to the relations above considered.

It is manifest at once that whether our new ideas respecting the present condition of Mars or Jupiter be correct or not, the general argument de-

ducible from the analogy of our own earth remains unaffected. If Mars and Jupiter be at this moment inhabited by living creatures, it can only be because these orbs happen to be passing through the life-supporting period of their existence. We have shown that there is strong reason for believing this not to be the case; but if it is the case, this can only be regarded as a strange chance. For we have learned from the study of our earth, that the life-supporting era of a planet is short compared with the duration of the planet's existence. It follows that any time selected at random in the history of a planet is far more likely to belong to one or other of the two lifeless eras, one preceding, the other following the life-supporting era, than to belong to this short era itself. And this present time *is* time selected at random with reference to any other orb in the universe than our own earth. We are so apt to measure all the operations of nature by our own conceptions of them, as well in space as in time, that as the solar system presents itself (even now) as the center of the universe, so this present time, the era of our own life, or of our nation's life, or of the life of man, or of the existence of organic beings on the earth, or (passing yet a grade higher) the era of our earth's existence as a planet, presents itself to us as the central era of *all* time. But what has been shown to be false with respect to space is equally false with respect to time. Men of old thought that the petty region in which they lived was the center of the universe. After this was shown to be false by Copernicus, Kepler, and Newton, men clung in turn to the conception that the solar system is central within the universe. The elder Herschel showed that this conception also is false. Even he, however, assigned to the sun a position whence the galaxy might be measured. But it begins to be recognized that this is not so. Nay, not only is the sun no suitable center whence to measure the stellar system, but the stellar system is for us immeasurable. The galaxy has no center and no limits; or rather we may say of it what Blaise Pascal said of the universe of space—its center is everywhere and its circumference nowhere. The whole progress of modern science tends to show that we must similarly extend our estimate of time. In former ages each generation was apt to regard its own era as critical in the earth's history; that is, according to their ideas, in the history of the universe itself. Gradually men perceived that no generation of men, no nation, no group of nations, occupies a critical or central position in the history of even the human race upon earth, far less in the history of organic life. We may now pass a step higher, and, contemplating the infinity of time, admit that the whole duration of this earth's existence is but as a single pulsation in the mighty life of the universe. Nay, the duration of the solar system is scarcely more. Countless other such systems have passed through all their stages, and have died out, untold ages before the sun and his family began to be formed out of their mighty nebula; countless others will come into being after the life has departed from our system. Nor need we stop at solar systems, since within the infinite universe, without beginning and without end, not suns only but systems of suns, galaxies of such systems, to higher and higher orders endlessly, have long since passed through all the stages of their existence as systems, or have all those stages yet to pass through. In the presence of time-intervals thus seen to be at once infinitely great and infinitely little—infinitely great compared with the duration of our earth, infinitely little by comparison with the eternities amidst which they are lost—what reason can we have when viewing any orb in space from our little earth, for saying *now* is the time when that orb is, like our earth, the abode of life? Why should life on that orb synchronize with life on the earth? Are not,

on the contrary, the chances infinitely great against such a coincidence? If, as Helmholtz has well said, the duration of life on our earth is but the minutest "ripple in the infinite ocean of time," and the duration of life on any other planet of like minuteness, what reason can we have for supposing that those remote, minute, and no way associated waves of life must needs be abreast of each other on the infinite ocean whose surface they scarcely ripple?

But let us consider the consequences to which we are thus led. Apart from theoretical considerations or observed facts, it is antecedently improbable that any planet selected at random, whether planet of our own system, or planet attending on another sun than ours, is at this present time the abode of life. The degree of improbability corresponds to the proportion between the duration of life on a planet, and the duration of the planet's independent existence. We may compare this proportion to that existing between the average life-time of a man and the duration of the human race.

If one person were to select at random the period of a man's life, whether in historic, prehistoric, or future time, and another were to select an epoch equally at random, save only that it fell *somewhere* within the period of the duration of the human race, we know how exceedingly minute would be the probability that the epoch selected by the second person would fall within the period selected by the first. Correspondingly minute is the *à priori* probability that at this present epoch any planet selected at random is the abode of life. This is not a mere speculation, but an absolute certainty, if we admit as certain the fact, which few now question, that the period during which organic existence is possible on any planet is altogether minute compared with the duration of that planet's existence.

The same relation is probably true when we pass to higher systems. Regarding the suns we call "the stars" as members of a siderial system of unknown extent (one of innumerable systems of the same order), the chance that any sun selected at random is, like our own sun at the present time, attended by a planetary system in one member of which at least life exists, is exceedingly small, if, as is probable, the life-supporting era of a solar system's existence is very short compared with the independent existence of the system. If the disproportion is of the same order as in the case of a single planet, the probability is of the same order of minuteness. In other words, if we select any star at random, it is as unlikely that the system attending on that sun is at present in the life-bearing stage as a system, as it is that any planet selected at random is at present in the life-bearing stage as a planet. This conclusion, indeed, may be regarded as scarcely less certain than the former, seeing that we as little doubt the relative vastness of the periods of our sun's existence before and after his existence as a supporter of life, as we doubt the relative vastness of the periods before and after the life-supporting era of any given planet. There is, however, one element of doubt in the case of the star. The very fact of the star's existence as a steady source of light and heat implies that the star is in a stage resembling that through which our own sun is now passing. It may be, for instance, that the prior stages of solar life are indicated by some degree of nebulosity, and the later stages by irregular variations, or by such rapid dying out in brightness as has been observed in many stars. Yet a sun must be very nebulous indeed—that is, must be at a very early stage in its history—for astronomers to be able to detect its nebulosity; and, again, a sun must long have ceased to be a life-supporter before any signs of decadence measurable at our remote station, and with our insignificant available time-intervals for comparison, are manifested.

As to higher orders than systems of suns we cannot speculate, because we have no means of determining the nature of such orders. For instance, the arrangement and motions of the only system of suns we know of, the galaxy, are utterly unlike the arrangements and motions of the only system of planets we know of. Quite possibly systems of sun-systems are unlike either galaxies or solar systems in arrangement and motions. But if, by some wonderful extension of our perceptive powers, we could recognize the countless millions of systems of galaxies doubtless existing in infinite space, without, however, being able to ascertain whether the stage through which any one of those systems was passing corresponded to the stage through which our galaxy is at present passing, the probability of life existing anywhere within the limits of a galaxy so selected at random would be of the same order as the probability that life exists either in a planet taken at random, or in a solar system taken at random. For though the number of suns is enormously increased, and still more the number of subordinate orbs like planets (*in posse* or *in esse*), the magnitude of the time-intervals concerned is correspondingly increased. One chance out of a thousand is as good as a thousand chances out of a million, or as a million out of a thousand millions. Whether we turn our thoughts to planet, sun, or galaxy, the law of Nature (recognized as universal within the domain as yet examined), that the duration of life in the individual is indefinitely short compared with the duration of the type to which the individual belongs, assures us, or at least renders it highly probable, that in any member of any of these orders taken at ramdom, *it is more probable that life is wanting than that life exists at this present time.* Nevertheless, it is at least as probable that *every member of every order—planet, sun, galaxy, and so onward to higher and higher orders endlessly—has been, is now, or will hereafter be, life-supporting "after its kind."*

In what degree life-supporting worlds, or suns, or systems are at this or any other epoch surpassed in number by those which as yet fulfill no such functions or have long since ceased to fulfill them, it would only be possible to pronounce if we could determine the average degree in which the life-sustaining era of given orbs or systems is surpassed in length by the preceding and following stages. The life-sustaining orbs or systems may be surpassed many thousandfold or many millionfold in number by those as yet lifeless or long since dead, or the disproportion may be much less or much greater. As yet we only know that it must be very great indeed.

But at first sight the views here advanced may appear as repugnant to our ordinary ideas as Whewell's belief that perhaps our earth is the only inhabited orb in the universe. Millions of uninhabited worlds for each orb which sustains life! surely that implies incredible waste! If not waste of matter, since according to the theory every orb sustains life in its turn, yet still a fearful waste of time. To this it may be replied, first, that we must take facts as we find them. And secondly, whether space or matter or time or energy appear to be wasted, we must consider that, after all, space and matter and time and energy are necessarily infinite, so that the portion utilized (according to our conceptions) being a finite portion of the infinite is itself also infinite. Speaking, however, on the subject we are upon, if one only of each million of the orbs in the universe is inhabited, the number of inhabited orbs is nevertheless infinite. Moreover, it must be remembered that our knowledge is far too imperfect for us to be able to assert confidently that space, time, matter, and force, though not utilized according to our conceptions, are therefore necessarily wasted. To the ignorant savage, grain which is planted in a field

instead of being used for food, seems wasted, the wide field seems wasted, the time wasted during which the grain is growing and ripening into harvest; but wiser men know that what looks like waste is in reality economy. In like manner the sun's rays poured on all sides into space so that his circling family receives but the 230 millionth portion, seem, to our imperfect conceptions, almost wholly wasted; but, if our knowledge were increased, we should perhaps form a far different opinion. So it may well be with the questions which perplex us when we contemplate the short duration of the life-sustaining condition of each world and sun and galaxy compared with the whole existence of these several orders. The arrangement which seems so wasteful of space and time and matter and force, may in reality involve the most perfect possible use and employment of every portion of space, every instant of time, every particle of matter, every form of force.

EARTHQUAKES.

It is related in the *Timæus* of Plato that the ancient Egyptians held the world to be liable to occasional widely-extended catastrophes, by which the gods checked the evil propensities of men, and cleansed the earth from guilt. Conflagrations, deluges and earthquakes were the instruments of the wrath of the offended gods. After each catastrophe mankind were innocent and happy, but from this state of virtue they gradually fell away, until their accumulated offences called for new judgments. Then the gods took counsel together, and unable to bear with the multiplied iniquities of the human race, swept them from the earth in some great cataclysm, or sent a devouring flame to consume them, or shook the solid earth until hills and mountains fell upon and crushed the inhabitants of the whole world.

One can understand how the confused records of great catastrophes, in which all, or nearly all, the inhabitants of wide districts were destroyed, led in the course of time to the formation of such views as Plato has described. And, indeed, it is not in one nation alone that we find theories of this sort prevalent. In the *Institute of Menu* the Hindoos are taught that at the end of each of those cycles of ages which are termed the "days of Brahma," all forms of life are destroyed from the earth by a great conflagration, followed by a deluge which inundates heaven itself. The mythical legends of the Chinese refer to similar views, which appear also in the Babylonian and Persian cosmogonies. The Chaldeans taught that when the planets are all conjoined in Capricorn the earth will be overwhelmed by a flood, and that when a conjunction of this sort takes place in Cancer the earth will be destroyed by fire.

In the present age when the network of telegraphy brings all parts of the earth into close intercommunication, we are not likely to trace, even in the most widespread disasters, the approaching destruction of our globe. The same day which brings the intelligence of some desolating catastrophe brings evidence also that the devastation is but local. We are seldom informed of simultaneous, or nearly simultaneous, events happening in widely-separated regions of the earth's surface. Accordingly, we are seldom led to dread the occurrence of any widely-devastating series of catastrophes.

We have heard a great deal lately of certain speculations—recently ventilated by an American philosopher—which threaten the earth with complete annihilation. According to these views there is one great danger to which we are at all times liable—the risk, namely, that some large volcanic vent should be formed beneath the bosom of ocean. Through

this vent the sea would rush into the interior of the earth, and being forthwith converted into steam by the intense subterranean heat, would rend the massive shell on which we live into a thousand fragments.

Whether it is possible or not that such an event as this should take place, I shall not here stay to inquire. Let it suffice that the risk—if there be any—is no greater now than it has been any time during thousands of past years.

But certainly, if there is any source from which the inhabitants of the earth may reasonably dread the occurrences of widely devastating catastrophes, it is from earthquakes. It is related that for full six months after the great earthquake of Lisbon, Dr. Johnson refused to believe in the occurrence of so terrible a catastrophe. "He spoke half jestingly," Macaulay thought—it is not easy to see on what grounds. To us it seems far more probable that Johnson heard with natural wonder and awe of the destructive effects of this fearful convulsion; and that for awhile he could scarcely believe that the extent of the disaster had not been exaggerated. It would be well if, indeed, the powers of earthquakes were less tremendous than they have been repeatedly shown to be. "There is," says Humboldt, "no other outward manifestation of force known to us—the murderous inventions of our own race included—through which, in the brief period of a few seconds or minutes, a larger number of human beings have been destroyed than by earthquakes." Lightning and storm, war and plague, are but weak and inefficient agents of destruction in comparison with the earth's internal forces.

And as earthquakes surpass all other phenomena as agents of sudden destruction, so the impression which they produce on those who for the first time experience their effects is peculiarly and indescribably awful. Men of reputed courage speak of a feeling of "intolerable dread" produced by the shocks of an earthquake, "even when unaccompanied by subterranean noises." The impression is not that of simple fear but a feeling of absolute pain. The reason seems for awhile to have lost the power of separating real from imaginary causes of terror. The lower animals, also, are thrown into a state of terror and distress. "Swine and dogs," says Humboldt, "are particularly affected by the phenomenon of earthquakes." And he adds that "the very crocodiles of the Orinoco, otherwise as dumb as our little lizards, leave the shaken bed of the stream and run bellowing into the woods."

Humboldt's explanation of the peculiar sensations of alarm and awe produced by an earthquake upon those who for the first time experience the effects of the phenomenon is in all probability the correct one. "The impression here is not," he says, "the consequence of the recollection of destructive catastrophes presented to our imagination by narratives of historical events; what seizes us so wonderfully is the disabuse of that innate faith in the fixity of the solid and sure-set foundations of the earth. From early childhood we are habituated to the contrast between the mobile element water and the immobility of the soil on which we stand. All the evidences of our senses have confirmed this belief. But when suddenly the ground begins to rock beneath us, the feeling of an unknown mysterious power in nature coming into operation and shaking the solid globe arises in the mind. The illusion of the whole of our earlier life is annihilated in an instant."

Use habituates the mind to the shocks of earthquake. Humboldt found himself able after awhile to give a close and philosophic scrutiny to the circumstances attending the phenomenon which had at first impressed him so startlingly. And he tells us that the inhabitants of Peru think scarcely more of a moderate shock of earthquake than is thought of a hailstorm in the temperate zone.

Yet the annals of earthquakes are sufficient to give rise to a feeling of dread, founded, not merely on the novelty of the event, but on a knowledge of the powers of the earth's internal heavings. The narratives of some of the great earthquakes afford fearful evidence on this point.

In the first shock of the great earthquake of Lisbon (November, 1755) the city was shaken to its foundations. The houses were swung to and fro so violently that the upper stories fell at once, causing a terrible loss of life. Thousands rushed to the great square in front of St. Paul's Church, to escape the reach of the tottering ruins. It was the festival of All Saints, and all the churches had been crowded with worshippers. But when the terrified inhabitants reached the square, they found that the great church of St. Paul's was already in ruins, and the immense multitude which had thronged its sacred precincts were involved in its destruction. Such of the congregations of the different churches as had escaped rushed to the banks of the Tagus for safety. There were to be seen priests in their sacerdotal vestments, and an immense crowd of people of all ranks and ages, praying to Heaven for mercy. As they prayed there came the second shock, scarcely less terrible than the first. The church on the top of St. Catherine's Hill was rocked to and fro till it fell, crushing in its fall a great multitude which had sought that height for safety.

But a far more terrible catastrophe was at hand. As the banks of the river sounded with the *Miserere* of the terrified supplicants who had crowded thither for safety, there was seen to pass over the wide expanse of the stream (here four miles broad) a strange heaving swell, though no wind stirred the air. The waters seemed to be drawn away to meet a vast wave which was now first observed to be bearing down upon the devoted crowd. They strove to fly, but the wave swept too rapidly onwards. The whole multitude was overwhelmed in a moment. A magnificent quay, lately built at a great expense, was engulfed with all who had crowded on it for refuge. Numberless vessels, also, which were anchored on the river and were now full of terrified people—seeking on an unstable element the security which the solid earth denied them—were sucked down by the tremendous wave, and not a trace of them was ever afterwards seen.

A third shock followed, and again the river was swept by a gigantic wave. So violently was the river moved that vessels which had been riding at anchor in deep water were flung upon the dry ground. Other shocks and other inroads of the river-water followed, each working fresh destruction, insomuch that many began to believe that "the city of Lisbon was doomed to be entirely swept away from the face of the earth."

It would be out of place to describe here at length how fire and pestilence came successively to complete the desolation begun by the earthquake's ravages. The terrible story has been narrated elsewhere. But what remains to be mentioned gives us startling evidence of the terrible energy of the earth's subterranean forces :—

The mountains Arrabida, Estrella, Julio, Marvan, and Cintra, some of the largest in Portugal, were shaken from their very foundations, they opened at their summits, and huge masses were flung into the neighboring valleys. Flames and smoke were emitted from the openings. But much farther away the effects of the great convulsions were experienced. It has been computed, says Humboldt, that a portion of the earth's surface four times greater than the whole extent of Europe was simultaneously shaken. On the coast of Sweden and on the shores of the Baltic, far away across the Atlantic to the Antigua Islands, at Barbadoes and Martinique, and still further off in the great Canadian lakes, the movement was sensibly felt. A vast wave of inky blackness swept over the West Indian seas, rising twenty feet above the level of the highest tides. In Algeria the

earth was as violently shaken as in Portugal, and eight leagues from Morocco a village with 8000 inhabitants was swallowed up.

The shocks felt at sea were so violent that the captains who experienced them thought their ships had struck the solid ground. A ship 120 miles to the west of St. Vincent was so violently shaken that the men were thrown half a yard perpendicularly upwards from the deck. Lakes and rivers in England were strangely agitated. The water in Loch Lomond suddenly rose against the banks without apparent cause, and then as suddenly subsided—the vibration of the earth's surface having traveled from Lisbon to Scotland at the rate of twenty miles a minute !

It has been calculated that in Lisbon alone 60,000 persons perished within the brief space of six minutes. But there have been other earthquakes in which even this terrible destruction of life has been surpassed. In 1603, 100,000 persons fell victims to the great Sicilian earthquake, and upwards of 300,000 persons are supposed to have perished in the great earthquakes which desolated Antioch in the sixth and seventh centuries. It has been estimated that within the last 4,000 years five or six millions of human beings have perished through the effects of earthquakes.

It is related that in the great earthquake of 1747 all the inhabitants of the town of Callao were destroyed, save one. The man who escaped, standing on a fort which overlooked the harbor, saw the sea retire to a distance and then return like a vast mountain in height. "He heard a cry of *Miserere* rise from all parts of the city," and in a moment all was silent —where the town had once flourished there was a wide sea. But the same wave which overwhelmed the town drove past him a small boat, into which he flung himself, and so was saved.*

OUR DUAL BRAIN.

In a recent lecture at the Royal Institution, Mr. Horsley offered evidence (which seems to me not very strong) against the theory of the duality of the mind. A person who, being already fairly well able to draw with either hand separately, attempts to draw simultaneously two different forms, however simple, with both hands, is tolerably sure to fail. Mr. Horsley appears to think that failure always results. When the effort is made, he says, "There is a very definite sensation in the mind of a conflict that is going on in the cortex of the brain. The idea of the circle alternates with that of the triangle, and the result of this confusion in the intellectual and sensorial portions of the brain is that both motor areas, though remembering, as it were, the determination of the experimenter to draw distinct figures, produce a like confused effect, namely, a circular triangle and a triangular circle."

Mr. Horsley adds that if the drawing is commenced immediately at the sound of a signal (as should always be done in such experiments), it will be found that the triangle predominates, while, on the other hand, if the two figures are not commenced simultaneously, the one last begun will appear most distinctly in the fused result, in fact, will very markedly predominate. He reasons upon this as follows:—"The idea of a triangle and circle having been presented to the intellect of the sensory centers, the voluntary effort to reproduce them is determined upon: now if we had a dual mind, and if each hemisphere was capable of acting *per se*, then we should have each intellectual area, sending a message to its own motor area, with the result that the two figures would be *distinct and correct*, not fused."

To this experimental evidence and to its interpretation two different an-

* It must be remarked, however, that Sir Charles Lyell estimates the number of the saved at 200, "of whom twenty-two were saved on a small fragment of the fort of Vera Cruz, which remained as the only memorial of the town after this dreadful inundation."

swers can be given. In the first place, it does not always happen that the attempt to draw two different objects simultaneously fails in the alleged manner. Setting on one side as probably exaggerated the story that Sir Edwin Landseer drew on one occasion a deer's head with one hand, while he was drawing a landscape with the other, I may cite from my own experience a case which entirely invalidates Mr. Horsley's evidence. My friend, Professor Edwin Morse, of Salem, Mass., could draw simultaneously, and that, too, before an audience, two different objects with either hand. Or, he would draw an object with one hand, and at the same time write the names of the parts of the object with the other. With practice much skill may be acquired in this ambidextrous work.

Here is a simple experiment to show the effect of practice. Try for the first time to write a word of so many letters while you spell aloud, letter by letter, another word containing the same number of letters. At first you are almost sure (perhaps quite sure) to fail. But after a few trials what had seemed impossible becomes feasible, and presently it becomes quite easy.

Then, even if it were proved that we cannot do two different things at once (apart from cases where either or both is done automatically), this would no more prove that the brain is not dual than our inability to use the two eyes simultaneously to do different work would prove that we have not dual vision.

As a matter of fact we are able to prove very easily that vision is double, by alternately closing and opening either eye. We cannot make any corresponding experiment with the brain. We do not know even that, when we are trying to do simultaneously two different things the two different sides of the brain are called into action. We have positively no means of determining whether one side, or the other side, or both sides of the brain shall be used, or of knowing whether they are used. Even in those cases where marked alternations of character, accompanied or preceded by marked cerebral phenomena, show unmistakably that two different parts of the brain may alternate in the regulation of actions and even of character, the person thus dually minded and charactered is perfectly powerless as to the particular mental side of him which shall come uppermost (or act alone). He often does not even know that he is passing or has passed from one state to the other.

Since, however, we are absolutely certain that each eye does its work, while we are absolutely unable to make them work separately yet simultaneously—to make one eye work at long range, for example, and the other at short range, the argument used by Mr. Horsley in regard to the brain is altogether without force.

If any one could make his two eyes work separately, I should be the one to do it, for my left eye is permanently limited to work at short focal distances, while the right eye has the usual range. Yet, not only am I powerless to make my two eyes work separately and simultaneously, but I am very seldom conscious of the fact that the left eye is in reality presenting to the brain (so to speak) a very different picture from that which is presented by the right eye.

I remained unconscious of the difference between the focal lengths of my two eyes, marked though it is (insomuch, that for ordinary distances my left eye is almost blind), till I was about twenty; at least I know it must have been more than twenty-six years ago that I detected the peculiarity. I was in church one Sunday evening, listening or not listening to a rather dreary sermon, in which a person whom I had reason for regarding little was enjoining duties which I had long learned to regard a great deal; and being naturally inattentive to him, I attended to other things. Now, there were in front of me two bright lights, and I noticed to the right of them two blurred lights, looking as large as

the moon, where assuredly no lights were. I looked at another group of lights, three of them—and lo, to the right of them also, a group of three, similarly arranged, blurred lights. I closed my left eye, and could see only the bright lights; I closed my right eye and could see only the blurred lights. That was all my left eye could do in the way of showing those lights.

Thus, for the first time in my life, I learned that so far as distant objects were concerned I was almost blind of one eye. But I soon found that my left eye was by no means blind for near objects; on the contrary, it was and is very keen for them. Yet I cannot make my eyes, different though they thus are, work separately, except in an imperfect sort of way, akin to the way in which, in Mr. Horsley's experiment, one hand makes a circular triangle while the other makes a triangular circle. I am well assured my vision is double, as all men are; nay, in my case vision is even of two kinds with the two eyes: yet I have precisely the sort of evidence respecting my two eyes which Mr. Horsley regards as evidence of unity.

Mr. Horsley cites a singular illustration of the duality of the mind, of which, however, he endeavors to dispose. The case is so remarkable, and, just now when all sorts of foolish superstitions are as rife as ever, so instructive, that I give its details here pretty nearly in full, as recorded by Prof. Ball, of Paris. He tells us that a young man, a patient of his, one morning heard himself addressed by name, and yet could see no one. He replied to this invisible, and in reality imaginary, interlocutor; and a conversation followed, in the course of which the ghostly visitor informed him that he—the visitor—rejoiced in the name of Gabbage. After this, he was often favored with visits from M. Gabbage. Unfortunately, the suggestions of M. Gabbage were generally open to objection. At one time M. Gabbage urged the patient to give an overdose of chlorodyne to a friend's child; at another, his idea was that the young man would do well to jump out of a second-floor window.

Prof. Ball thought — naturally enough—that the young man needed watching. It was presently found that the patient was suffering from one-sided hallucination; that is to say, a strong but false impression, affecting one side only of the brain, appeared to come from some external cause, the healthy side rejecting the evidence as false. (Without doubt many superstitions, many false religious beliefs, and also many crimes, have been suggested in this way.)

Mr. Horsley finds nothing in this or similar cases to suggest the duality of the brain; but I take it that the evidence is precisely analogous to that which showed me not only the duality but the diversity of my own visual powers. Usually, of course, the two sides of the brain would give the same sort of evidence respecting external objects; just as—usually—the two eyes do: but in certain cases one side of the brain is defective or peculiar in some way or other, and so gives evidence which the better and sounder side rejects; just as in my case one eye gave evidence of large diffuse lights where I knew, from the sound evidence of my better eye, that small bright flames were burning. The analogy seems as perfect as it can be; and the necessary conclusion is that the brain's action, in ordinary cases, is as essentially dual as the action of the eyes in vision.

A NEW STAR IN A STAR CLOUD.

The discovery of a new star in the midst of the Great Nebula in Andromeda must be regarded as one of the most remarkable astronomical events of the age. It is true that great changes have ere now been recognized in stars lying within nebulous clouds. The star Eta Argûs for example, which lies in the midst of that wonderful

mass of luminous gas called the Keyhole Nebula in Argo, has changed so marvelously in luster since it was first catalogued as a fourth magnitude star as to present a case corresponding so far as the star is concerned with the sudden appearance of the new star in the Andromeda Nebula. For Eta Argûs sank from the fourth magnitude to the sixth, then rose rapidly to the second, and after remaining for some time at that magnitude increased almost suddenly in splendor until it rivaled Canopus and was surpassed only by Sirius. Undoubtedly to an observer set at such a distance that Eta Argûs when thus resplendent would have appeared only as an eighth magnitude star, like the new star in Andromeda, Eta with its present light of a sixth magnitude star would be altogether invisible. So that viewed from that imagined distance Eta Argûs when it rose to its greatest splendor would have appeared as a new star, and as it faded out of view would come to be regarded as having been but a temporary star.

Again, the star which appeared in Cygnus in 1876 must be regarded as a star which had suddenly shone out in a nebula, although no nebula had been known where the star appeared. For when that star had disappeared there still remained a blue planetary nebula in the place which the star had occupied. And this nebula was and is so faint that one can readily understand it having escaped notice before. No one, I imagine, can doubt that the nebula which is seen there now existed there before the star appeared.

The stars in the great Fish-mouth Nebula in Orion exhibit also a certain degree of variability, which, though not so striking as the appearance of "new stars," is in reality a phenomenon of the same sort. For every so-called "new star" may be regarded as a variable of an unusually irregular kind.

But in all these cases the star which shone with variable luster, or which for a time appeared as a new star, has been in the midst of a gaseous nebula. The great nebula in Andromeda has always been regarded as a stellar nebula, although it has never been resolved into stars. Under spectroscopic examination it presents the rainbow-tinted streak crossed by absorption lines which indicates the existence of glowing solid or liquid or highly compressed vaporous matter shining through absorptive vapors. I remember Dr. Huggins describing the spectrum of this object to me, during a visit which I paid to his observatory in 1866; and he then said that the spectrum differed only from that of a star, in being rather sharply cut off at the red end, as if through the action of vaporous envelopes more powerfully absorptive of red light than the vapors around our sun and most other stars.

In a rather carelessly-written paragraph in the *Times* of Saturday last,* manifestly by a person not well acquainted with astronomical facts, the new star is spoken of as if it gave support to Laplace's nebular theory. In reality the appearance of the star is most strongly opposed to that theory, for the simple reason that all the processes involved in Laplace's nebular theory are slowly-acting ones, while the appearance of a new star where a star had not before been visible, signifies events of a catastrophic nature. Moreover the theory of Laplace, in the form in which it was presented, cannot be maintained by any one acquainted with the laws of physics. A vast disc of gaseous matter, extending beyond the orbit of Neptune, but containing no more matter than there is in the whole solar system would not have the slightest cohesion among its various parts. To conceive of it as rotating like a single mass is to imagine the impossible. One may say indeed of Laplace's nebular hypothesis—which was very properly regarded by himself as but a guess—that astronomers suppose it physically possible and physicists suppose it astro-

* This article was first published Sept. 11, 1885.

nomically possible: but no one who combines a knowledge of both astronomy and physics can accept it in the wide generality of its original form.

What the new star really does throw light upon, and light of a very clear and unmistakable sort, is not the theory of the solar system, but the theory of the stellar system—that grand gathering of stars, star-clusters, star-clouds, and star-streams, which we call the galaxy.

If there was one member of the family of nebulæ which was still supposed to remain possibly an external galaxy, after all the evidence which had been collected to show that nebulæ belong to our own galaxy, it was the great nebula in Andromeda,—the transcendently beautiful queen of the nebulæ as the old astronomers enthusiastically called it. Mr. Herbert Spencer observed as far back as 1859 or 1860, in his fine essays on the Nebular Hypothesis in the *Westminster Review*, that the theory according to which numbers of the resolvable nebulæ are external star systems is absolutely untenable. He pointed to this fatal objection, that Sir William Herschel's most powerful telescopes failed to resolve the remoter portions even of our own galaxy. How then could they—or indeed in many cases much weaker telescopes—by any possibility resolve galaxies lying far beyond its limits. A resolvable nebula which has an apparent greatest diameter of a quarter of a degree of arc, would be a very large one indeed; yet even one of that apparent size must lie at a distance exceeding its own diameter about 230 times, and exceeding therefore (supposing that nebula a galaxy like our own in size) the distance of the outskirts of our galaxy from us, more than 450 times. This would correspond to a diminution in the luster of individual stars more than 200,000 times. Now Herschel had to withdraw from the survey of the remotest parts of our galaxy, or at any rate the least resolvable parts (for my own interpretation of their irresolvability does not assume great distance as a necessary point), satisfied, as he said, that those depths are unfathomable. Irresolvable nebulosity foiled his most powerful telescopes, within the limits of our own stellar domain. How preposterous, then, when considered a little, the belief that the same telescope which failed to resolve the outskirts of our own galaxy, can bring into view individual stars having less than the 200,000th part of the light of those remoter suns of our stellar system.

Mr. Herbert Spencer pointed out another fatal objection, in Sir W. Herschel's own account of the arrangement of the stellar and nebular groupings. For Herschel said that whenever he found his star gauges running poor, he would call out to his elder sister, Miss Caroline Herschel, who acted as his assistant, "Prepare to write, nebulæ are about to appear." This peculiarity of arrangement by which nebulæ fit in where stars are sparsely strewn, and *vice versâ*, must be regarded as proof positive of the association between nebulæ and stars. Nebulæ must belong, then, to our galaxy.

I myself collected some forty pieces of evidence as to the structure of our galaxy, by which, as I believe, the old-fashioned theory (in favor of which not a single direct argument has ever been adduced) was shown to be absolutely untenable. I may remark in passing that I propose to publish in the first monthly number of the new series of *Knowledge* a letter which I addressed to Sir John Herschel in 1870, wherein the greater number of the arguments on which the objections to the old theory are based were briefly indicated. In the second number of that series I propose to publish his singularly interesting reply to that communication. I feel that the time has come to make known precisely how that great astronomer viewed the questionings then being addressed to the theory with which—not quite correctly—his own name and his father's have been associated.

But while Mr. Spencer's objections

(of themselves) sufficed to demonstrate the utterly untenable nature of the theory of galaxies of stars external to our own stellar system; and my own more labored gathering of evidence on the subject should have left no doubt, even in the minds of those least ready to recognize the force of reasoning in such matters, the great nebula in Andromeda was in some degree outside our evidence.

The Andromeda nebula is not gaseous but manifestly stellar; yet it has not been resolved into stars. Nor had it been possible to show how far the nebula was from resolvability. Some, using very powerful telescopes on the nebula, supposed they had come very near to resolving it into discrete stars; but they could not feel sure on such a point. For anything yet shown, telescopes a thousand times more powerful than the great Rosse telescope (imagined for the moment as perfect in defining power) might have failed to resolve the Andromeda nebula into stars.

Therefore Mr. Herbert Spencer's first objection, fatal against all resolved or partly-resolvable nebulæ, had no *fatal* force (it had considerable force however) against the Andromeda nebula. Of course the other objection had no force at all if this nebula is once regarded as exceptional. Among all my own objections against the theory of external galaxies, few had much force against the Queen of the Nebulæ, and certainly none were absolutely decisive against this great agglomeration of unquestionably stellar material being an external galaxy.

Now, however, it need hardly be said, the question is disposed of. A star-cloud cannot possibly be an external galaxy resembling our sun if there can appear in it suddenly a star where no star had before been seen. Were the Andromeda nebula such a galaxy the change which has recently taken place in it (or to speak more precisely, the change of which the light-brought news has recently reached us) would correspond to such a change in our galaxy as would alter its whole character. A star millions of times larger than any orb in our galaxy would have to be present in it—to begin with—and then after being so dull as to give no more light than an ordinary sun—would have to blaze out suddenly with hundreds of thousands of times as much light even as the splendid Sirius pours forth, to produce such a change of aspect in our galaxy, supposed to be seen from the distance of the Andromeda nebula, as has actually taken place in that star-cloud.

The theory that the star-clouds, or any of them, are external galaxies has received a death-blow. This is not saying it was not dead before. The blow may be such a one as Falstaff gave the dead Percy: but no one can mistake its force. With this new wound the theory has no longer even the semblance of life, and will possibly disappear ere long from those cemeteries for defunct theories, the text-books!

MONSTER SEA-SERPENTS.

I have been gratified and rather amused to find a short article, which I contributed more than a year since to *The Newcastle Weekly Chronicle* on the subject of a marine monster seen near Panama, appearing in the very valuable report of Professor Spencer F. Baird, United States Commissioner of Fish and Fisheries. A genial article in the *New York Tribune* for January 4, 1885, presents my recognition of this marine monster and defence of the sea-serpent as a tardy admission on the part of science that there may be more things in sea and land than had been dreamt of in an unphilosophical philosophy. But so far as I am concerned there has been no "ridicule, followed by denial, then by doubt, and lastly by partial acceptance." I have always been a believer in the sea-serpent of Capt. McQuhae, of the *Dædalus*. I was a very young lad when his report of the

strange encounter first appeared; but it seemed to me then, and it seems to me still, that the sea captain had much the best of the discussion with the representatives of science. There was that cautious naturalist and palæontologist, Richard Owen, so anxious to disprove the sea-serpent that he pictured to himself the captain and officers of a British frigate frightened out of their wits, and out of one at least of their senses, by the sight of a sea-elephant (as he tried to make out) rather far away from its native abode, and urging its course as fast as possible homeward. Captain McQuhae, in a report to the Admiralty, says that he and his officers saw a long-necked sea monster traveling swiftly in the teeth of a ten-knot breeze on the surface of the sea, so quickly that he could see the waves frothing against the creature's chest. It passed so near that he could have distinctly seen the features of a man at the distance. He and his officers had a good view of the creature. (For a wonder, they were not possessed by the customary desire to shoot it, a desire which speaks as honorably of the human race as the saying of the North Country miner immortalized by Leech, who, seeing a stranger, thought it due welcome to "'eave 'arf a brick at un.") They rejected the sea-elephant with derision, as entirely inconsistent with what they had clearly seen; while the idea of their being frightened—well, Americans in old times tackled a few of our British frigates with greater or less success, but they did not find our seamen quite so timorous as to be likely to tremble in their shoes at the sight even of an extra large sea-elephant. Yet Prof. Owen persisted in his belief that the *Dædalus* sea-serpent story was not worthier of credence than a story about ghosts. That particular ghost he thought he had laid.

Since then all sorts of explanations of sea-serpent stories have been advanced. Because one captain has mistaken a lot of floating sea-wreck half a mile away for a sea monster, therefore the story of a sea creature seen swiftly advancing against wind and sea, at a distance of less than 200 yards, meant nothing more than misunderstood sea-weed. Another mistakes a flight of birds in the distance or a shoal of porpoises, or even a range of hills beyond the horizon, for some sea-sepentine monster, and forthwith other accounts, however manifestly inconsistent with such explanations, are regarded as explained away. Then, worst of all, some idiot invents a sea-serpent to beguile his time and find occupation for his shallow pate, and so soon as the story is shown to be only a story, men of sense and standing, as incapable of the idiocy of inventing sea-monsters as I am of inventing a planet, are supposed to have amused their leisure by sending grave reports of non-existent sea-monsters to men under whom they (the seamen, not the sea-monsters) held office, or by taking oath before magistrates that they had seen sea creatures which they had invented, and by parallel absurdities.

All this has been done in the case of the sea-serpent, as something akin to it was long since done in the case of the cameleopard, and later in the case of the gorilla. Much earlier Herodotus had been called the Father of Lies instead of the Father of History, because of wonders related by him which have since been shown to be facts. The poor (in intellect and veracity) are always with us; and they can never admit that anything exists outside what they know, or understand how any traveler in little known regions can fail to lie lustily when he comes home again. Among the creatures thus specially ridiculed the monster earth-worm described by Rapp, some forty years ago, was specially ridiculed, and those who believed in it, or declined utterly to reject it, were sneered at just as those who recognize the reasonableness of the sea-serpent are laughed at now. Rapp said he had seen in South Africa a monstrous earth-worm, sev-

eral feet in length. One of these he described as 6 ft. 2 in. long, and proportionately thick. The measurement was regarded as not worthier of credence than Gulliver's precise statements of the height of Lilliputian and Brobdingnagian animals. The absurdity and impossibility of the thing was abundantly proved. A worm of the ordinary kind averages, let us say, 6 in. in length. Here, if this lying traveler was to be believed, was an animal more than twelve times as long, and therefore some 1,800 times as large. Now, the ordinary boa-constrictor is about eighteen feet long. Multiply his length by twelve, and we get a serpent of 216 feet in length. *Credat judæus*, &c. Rapp was demonstrably a vendor of lies—so, at least, said the young buccaneers of the press. Well, there is now in the Zoological Gardens in London a living specimen of the species described by Rapp. It is not one of the largest. Indeed, these creatures are hard to catch and keep alive; and probably the biggest are the most difficult to secure. They are described as "fairly abundant in the neighborhood of Port Elizabeth and other parts of Cape Colony," but they keep out of sight unless heavy rains drive them out of their holes, when hundreds of them can be seen crawling about, but they usually perish soon after thus visiting the surface. The specimen at the Zoological Gardens is about five feet long, however, so that it is quite a good-sized worm. Here, then, is a case where a creature, the description of which excited as much ridicule as that of the sea-serpent, is found not only to exist in large numbers, but to be amenable to the customary treatment extended by our kindly race to the inferior races: we have captured a specimen and keep it on show.

Yet those who formerly laughed at the earth-worm laugh now about the fancied sea-serpent. They laugh so consumedly, and make so much noise over it—the laughter of such folk being "as the crackling of thorns under a pot"—that, as my friend Mr. W. Mattieu Williams points out, and as I can confirm, "much valuable evidence concerning the sea-serpent is suppressed by the flippant sneering of the class of writers who require no other qualification than ignorance of the subject on which they write. Scores, perhaps hundreds, of trustworthy mariners of all ranks, in both the naval and mercantile services, have seen what they believe to be such a creature, but they refuse to publish any account of their observations, knowing they will be insulted, and publicly gibbeted as fools and liars if they do."

The foolish laughed in the same way over the kraken, as you point out, and the monster they rejected as impossible has been killed and measured. Whether the sea-serpent, or any creature whose prey is chiefly sought at a considerable distance below the surface, will ever be captured or killed is very doubtful. But their existence ought never to have been regarded as doubtful after the evidence gathered in Massachusetts in 1817, and the report of the captain of the *Dædalus*. There are probably several varieties of sea-creatures which look like serpents, and among these varieties some may quite probably be really serpentine. But some of the supposed sea-serpents must have really propelled themselves otherwise than as serpentine sea-creatures do. For they moved rapidly along the surface without perceptible undulations, and nothing but concealed paddles could have urged them on in this way. In my article on "Strange Sea-Creatures," which appeared eleven years ago in *The Gentleman's Magazine*, several singular inhabitants of the sea—and in particular a monstrous skate seen in the East Indies—are described, and evidence given to show that even among comparatively familiar species new varieties are from time to time being discovered. Thus, though no sea-serpent so large as the Sea Orm or Sea Worm, described by Bishop

Pontoppidan as six hundred feet in length, have as yet been seen, it does not follow that none such exist, albeit, I cannot doubt that the good Bishop's accounts are very largely exaggerated. He was not quite so foolish as the modern critic, who, though he perhaps has never left his native town, undertakes to contradict men who describe what they have seen. But I fear he erred as far in the opposite direction. The boa-constrictor and the condor have been described in such terms by comparatively modern travelers (as Humboldt has shown) as would suggest creatures akin to the serpent which went for Sindbad, and the roc which also adorns Sindbad's narrative and appears elsewhere in tales of the East. But to exaggerate is one thing, to invent is another. The man who is foolish enough to lie about his traveling experiences is not capable of inventing a new animal worth five minutes' consideration; but, on the other hand, the man who, being sensible, is honest and truthful, is yet very apt to err in the way of unintentional exaggeration. I think poor Capt. Drevar's narrative of a long-necked sea monster which captured in its folds and took down a sperm whale was a little exaggerated, though he and his mates swore to the truth of the story before a magistrate, and he himself was most unfairly punished by his employers for telling what he had seen—he was, in fact, ruined for life. ("I would not tell about it," said an old salt to Capt. Drevar, "if I saw five hundred seasarpints.") But I no more believed that these men would have invented such an animal if they could, or could have invented it if they would, than I believe that an utterly ignorant man could have devised the famous Lunar Hoax—the clever story respecting a powerful telescope showing living creatures in the moon. Yet that story did not, as was alleged, take in Arago; no one acquainted with optical laws could have been deceived by it for an instant. To imagine that sailors could accomplish the far more difficult feat of inventing a new kind of animal, without immediately exposing their ignorance to every one acquainted with the laws of comparative anatomy, is to imagine the impossible.

THE ORIGIN OF COMETS.

Encke's comet has returned to our neighborhood, and is now (February, 1885) under observation. Yet to all ordinary appearance our skies are unchanged. Those who associate the return of a comet with the appearance of an awe-inspiring object, with long, sword-like tail brandished athwart the heavens, like those comets which have in past and recent ages terrified the nations, are disappointed when they hear that the comet of which the papers speak, and which Professor Young re-discovered a few days ago, and our telescopists are carefully observing, is one which cannot even be seen without telescopic aid. Yet to the student of astronomy the triumph is greater when one small comet is caught in the toils of mathematical analysis, and detected as it advances along its return track, than when the most glorious new comet blazes in our skies, and by rapid changes of position and of form attracts the admiring attention of all men.

I propose to make the return of Encke's comet—the comet of shortest period known—the text for some remarks about the theories of comets more or less in vogue among astronomers, and especially those theories which relate to the origin of these bodies, or at least their introduction into our solar system.

It may be remembered that at the last meeting of the American Association for the Advancement of Science, Professor Young touched on what he called the received theory of the origin of comets, and what he admitted was a valid objection of mine against that theory.

What Professor Young calls the received theory is, I take it, neither a theory nor generally received—it only comes in company with a received theory. Schiaparelli, the ingenious chief of the observatory of Milan, threw out, in 1866, the idea that the bodies which produce the star-showers of Aug. 10 and 11 (the *Tears of St. Lawrence* they were fancifully called in old times) are attendants on the Comet of 1862. When he had shown, which was an easy thing to do, that the apparent movements of those falling stars on the stellar heavens accord with the theory that they are moving in parallel tracks, touching (at any rate) the orbit of that comet at the place where it crosses the earth's track (a point passed by the earth on or about Aug. 10–11), it was felt that he had done something in support of his hypothesis. But when Professor Adams had shown, which was by no means an easy thing to do, that the bodies producing the display of November meteors travel in the very track of the comet of 1866 (known as Tempel's), astronomers saw that Schiaparelli's case was proved. It passed thenceforward from the condition of a mere speculation to that of a received theory.

This is the received theory about comets and meteors which every astronomer who can understand the evidence accepts without hesitation—*Meteors are bodies which travel on the tracks of comets.* More than that has not yet been shown, and more than that is certainly not received by astronomers as a body.

But Schiaparelli suggested more. He threw out a speculation concerning the origin of comets based on his established theory as to the connection between comets and meteors. This speculation would explain, if established, the way in which meteors travel on the tracks of comets. It ran as follows :—Amidst the interstellar depths are flights and clouds of meteoric bodies, which from time to time are drawn out of those depths by the attractive influence of the sun. Were the sun alone in the universe they would be drawn toward him, sweep around him in greater or less proximity to his surface according to the course on which they chanced to be drawn, and so pass out again to the depths from which they came. But as the sun has a family of attendant planets and some of these are somewhat stalwart fellows, many of the meteor-flights drawn sunwards are so acted upon by the disturbing influence of Jupiter, or Saturn, or Uranus, or Neptune, or mayhap some outer and still unknown members of the family of giant planets, that they are deflected from their course and thenceforward travel on a closed path —elliptic, of course—around the sun. The place where the deflection took place remains thenceforward a part of the comet's path, which therefore seems to associate itself with the path of the deflecting planet, in such sort that, though the sun is the chief ruler of the comet, the planet which introduced it into the solar system retains a sort of secondary influence over the comet's movements. Should the comet chance to revisit the scene of deflection when the planet is passing the same place, potent disturbing influences may be exerted on the comet, which may even send it wandering yet once more into the domain of interstellar space whence, according to this speculation, it was drawn.

Now, I pointed out more than eleven years since that this part of Schiaparelli's imaginings is entirely without foundation in known facts. We may *guess* that the interstellar depths are a sort of breeding-place for comets and meteor systems,—though why they should be so not even Schiaparelli has ventured a suggestion. We may imagine that in the interstellar depths there still remain the scattered fragments of such materials as, when gathered in, had formed our solar system with all its worlds ; though why any such fragments should remain *there*, instead of responding to the influences which brought their fellows to the neighbor-

hood of our system, would remain still unexplained. Only five or six millions of years would be required to draw in matter to the sun from half the distance separating him from his nearest neighbor among the stars, and our earth's crust tells us of tens of millions of years already passed since the sun had gathered in his mass so as to shine as a sun upon the earth. But we may concede for a moment the possibility of the wandering meteor flights of interstellar space imagined by Schiaparelli. How are we thereby helped to an interpretation of the origin of meteor systems now in attendance on the sun? Not a whit, seeing that we have only succeeded in replacing one difficulty by another still greater.

If we suppose the meteor streams to have come into the interstellar depths from beyond, that is from the domain of some star, we have removed our difficulty only a step, and not a step bringing us any nearer a solution. That other star is a sun like ours, and if a meteor system came from it to us, we have the same difficulty in understanding how the meteor system came to be in the neighborhood of that sun as we have in understanding it as belonging for a while to our own sun. One may compare this attempt at a solution of a really serious difficulty to Sir William Thompson's well-known attempt to explain the origin of life in our planet. This he did by surmising that millions of years ago another planet was the abode of life, that that planet came unfortunately into collision with another or burst, and that some of the fragments after flitting from sun to sun a few times chanced in their passage through our solar system to encounter our earth, where, falling on good soil, the germs brought forth abundant life: development did all the rest. That planet may have inherited the germs of life from another which had burst or collided a few millions of years before, and so on; we may in fact adopt a theory of planetary life akin to the theory of individual life—*omne vivum ex ovo*—and say every live planet received its life from a planet which was full of life, but burst up. Schiaparelli's cometic speculation asserts in like manner that every meteoric system or comet now associated with the sun came here athwart the star depths from another sun with which, millions of years ago, it was in like manner associated.

All this, however, is not scientific theorizing but speculation. There is no evidence in support of Schiaparelli's supposition. If it were established we should be as far off as ever from knowing the real origin of comets. But lastly, there happens to be demonstrative evidence against the theory:—

Take the November meteors, whose path crosses that of Uranus so closely as to show that Uranus was the planet which introduced this particular meteor system, if the theory has in it any truth at all. The November meteors, and of course Tempel's comet, in whose track they travel, cross the path of Uranus now with a velocity of 1½ miles per second. A meteor coming to our sun from interstellar space would cross the track of Uranus, if it chanced to come in the right direction, with a velocity of nearly 6 miles per second. Uranus, then, to do what certainly *has been done* if Schiaparelli's idea is right, must have abstracted a velocity of 4½ miles per second from every one of a flight of meteors traveling past it. Now it may be barely possible (I doubt if it is, but the calculations necessary are too abstruse to be entered on save for a very special purpose) for Uranus to abstract so great a velocity from a body traveling past him. If Uranus drew a body to himself from interstellar space, no other member of the solar system, not even the sun, interfering, he could give to the approaching body a velocity of 13½ miles per second; but he could not give any thing like this velocity to a body rushing along by him with sun-imparted velocities, and therefore

exposed for a shorter time to his influence. Moreover, in any passage by Uranus some part of the velocity abstracted or added in one part of the passage would be restored or taken away again in the remaining part. At the utmost, Uranus might abstract from a single meteor some 4½ miles per second of its velocity of 6 miles per second. But Uranus could not possibly produce the same effects on the members of a flight of meteors, however closely we may conceive them to be set. Some would have their velocities much less effectively reduced. And the deflections of direction would be also altogether different. Nothing could save a meteor-flight from being dispersed along widely divergent paths if it came near enough to Uranus to have the motion of any of its members sufficiently affected to make them travel henceforward in such an orbit as is actually pursued by the November meteors, which all travel along the same path.

This which is true of one meteor system or comet is true of all. Under no conceivable conditions could a meteor-flight be introduced into our solar system as Schiaparelli imagined. Hence a different theory of the origin of the families of comets associated with the giant planets must be adopted. We *must* in some way admit that every comet was once in the neighborhood of one of the giant planets in the form of a closely-set flight of meteors. This being so, the natural explanation is that each comet started from a planet,—by a process akin to volcanic ejection, or in some such way. Now, on the one hand the sun does eject bodies from his interior, in mighty eruptions which have been actually watched; and the planets when in the sunlike state may well be believed to have done likewise; and on the other hand there is evidence to show that even our small earth once possessed the power of ejecting meteoric bodies from her interior (Prof. Ball considers that some meteor-flights still in existence were earth-born).

On the whole, then, the view seems suggested that comets like Encke's were ejected from the interior of the planet on which they are still found to be dependent.

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